



THE  
AMERICAN NATURALIST

---

VOL. XXXVI.

May, 1902.

No. 425.

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THE LAW OF ADAPTIVE RADIATION.

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ONE of the essential features of divergent evolution as conceived in the branching system successively developed by Lamarck, Darwin, Huxley, and Cope has been termed by the writer "adaptive radiation." This term seems to express most clearly the idea of differentiation of habit in several directions from a primitive type, as shown in the accompanying diagrams. The law is a familiar one; it results in the formation of analogous radii in different groups of animals. The first comprehensive illustration of the law known to the writer is that under the headings "Homologous Groups" and "Heterology," in Cope's paper of 1868 on the "Origin of Genera," reprinted in the *Origin of the Fittest* (pp. 95-106). This brilliant essay is marred only by great confusion in the use of terms; but the parallelisms in unrelated groups of amphibians and of mammals such as marsupials and placentals, as first observed by Owen, are clearly brought out.

In the present paper citations from earlier essays of my own may be given bearing upon *general adaptive radiation* and the independent production of analogous radii under the convergent

principles of homoplasy, parallelism, and convergence, which, as shown in the last number of the *Naturalist*, are by no means synonymous terms or identical processes. The altogether similar law of *local adaptive radiation* or incipient divergence on a smaller scale in a single locality may now be more clearly developed.

This idea of radiation becomes a means of interpretation, and a way of imagining the relations of extinct and living faunæ. As perceived by Cope, it applies both on a small and on a vast scale.

#### I. GENERAL RADIATION.

In the "Rise of the Mammalia" ('93, pp. 30-33) the ancient Mesozoic (Meseutheria) and modern Cenozoic (Ceneutheria) differentiation of the placentals (Eutheria) was spoken of as follows:

The Puerco is essentially an archaic fauna, and is to be regarded as the climax of the first period of placental differentiation, a culmination of the first attempts of nature to establish insectivorous, carnivorous, and herbivorous groups. These attempts began in the Cretaceous, and some of the types thus produced died out in the Puerco, some in the Wasatch and Bridger; only a few flesh-eaters survive to the Miocene. It is most important to grasp clearly the idea of this *functional radiation* in all directions of this old Puerco fauna, resulting in forms like the modern insectivores, rodents, bears, dogs and cats, monkeys, sloths, bunodont and selenodont ungulates, and lophodont ungulates. This was an independent radiation of placentals, like the Australian radiation of marsupials.

Some of the least specialized spurs of this radiation appear to have survived and become the centers of the second or mid-Tertiary radiation, from which our modern fauna has evolved. Yet we have not in a single case succeeded in tracing the direct connection.<sup>1</sup> To sum up, we find on the North American continent evidence of the rise and decline and disappearance of monotremes and marsupials, and two great periods of placental radiation, the *ancient radiation* beginning in the Mesozoic, reaching a climax in the Puerco and unknown post-Puerco, and sending its spurs into the higher Tertiary, and the *modern radiation* reaching its climax in the Miocene, and sending down to us our existing types.

<sup>1</sup> This statement has been modified by subsequent discovery.

In the "Origin of the Mammals" ('99, p. 92) the idea was developed as follows :

To guide our speculation in the unknown pre-Tertiary period, we may gather certain positive principles from the known evolution of the Tertiary Mammalia. First, we know that *adaptive radiation*, characteristic of all vertebrates, and beautifully illustrated among Reptilia, is in a very high degree distinctive of Mammalia, because of their superior plasticity.

The *focal-types*, or most primitive forms of the radiations, I-IV, were certainly small, terrestrial, clawed, insectivorous or omnivorous forms. It is noteworthy that in the evolution of each radiation, so far as we know at present, land types and organs are invariably primitive, and water types and organs are secondary, exactly as we find among the Reptilia. In fact, we have not found a single instance in which a mammal or reptile series is known to be transformed from a water into a land type; it is always the reverse. There is certainly no evidence for a cetoid (Albrecht) stem of the Mammals. Again, it is obvious that neither carnivorous nor herbivorous types with highly specialized or reduced teeth and feet can be so central as insectivorous and omnivorous types. In fact, the Insectivores among Placentals, and Opossums among Marsupials, are the only animals which have preserved the dental prototype close to that of the Promammal.

The radiations spoken of in this essay were :

- I. *Marsupial Radiation of Australia* (Metetheria).
- II. *Tertiary Placental Radiation of the Northern Hemisphere*, i.e., *North America, Asia, and Europe* (Ceneutheria).
- III. *Tertiary Placental Radiation of South America* (Ceneutheria).
- IV. *Cretaceous Placental Radiation of North America* (Meseutheria).
- V. *Jurassic Radiation of Placentals and Marsupials*.

In a subsequent paper, "The Geological and Faunal Relations of Europe and America during the Tertiary Period, and the Theory of the Successive Invasions of an African Fauna" ('00), the subject was further developed as follows :

Now it is a well-known principle of zoological evolution that an isolated region, if large and sufficiently varied in its topography, soil, climate, and vegetation, will give rise to a diversified fauna according to the law of adaptive radiation from primitive and central types. Branches will spring off in all directions to take advantage of every possible opportunity of securing food. The modifications which animals undergo in this adaptive radiation are largely of mechanical nature, they are limited in number

and kind by hereditary, stirp, or germinal influences, and thus result in the independent evolution of similar types in widely separated regions under the law of *parallelism or homoplasy*.<sup>1</sup>

## II. ADAPTIVE RADIATION OF ORDERS AND FAMILIES AS BEARING ON GEOGRAPHICAL DISTRIBUTION.

This law causes the independent origin not only of similar genera but of similar families and even of similar orders. Nature thus repeats herself on a vast scale, but the similarity is never complete or exact. When migrations are favored by over-population or geographical changes, a new and severe test of fitness arises by the mingling and competition of the parallel types.

Under the operation of these laws a most interesting generalization or hypothesis can be made as to the three [zoological] realms: geographical



FIG. 1. — Orders of mammals placed in their hypothetical chief centers of adaptive radiation during the Tertiary period. (From Osborn.)

isolation has been so continuous and prolonged that great orders of mammals have been evolved . . . in each. Thus *Arctogaea*, containing the broadest and most highly diversified land area, appears hypothetically as the center in which fourteen primitive and specialized orders radiated from each other. In the southern portion of *Neogaea* at least four orders sprang from primitive members of the above orders, and the Hystricomorph rodents enjoyed their chief radiation. In *Notogaea* two orders were cut off by the sea; one of them a rapidly declining type, the Monotremes, the other, the Marsupials, enjoying a very highly diversified radiation. This

<sup>1</sup> At this time the distinction between homoplasy and parallelism was not appreciated by the writer.



hypothesis is expressed in Fig. III [Fig. 1]. The other orders of mammals, the Sirenia (probably a branch of the hoofed tribe), took the rivers and coasts of America, Europe, and probably Africa as their radiating center, while the Cetacea occupied the fourth or oceanic realm.

We mean to express by this hypothesis that REALMS [Fig. 2] *were the main centers of adaptive radiation of orders of mammals*, but by no

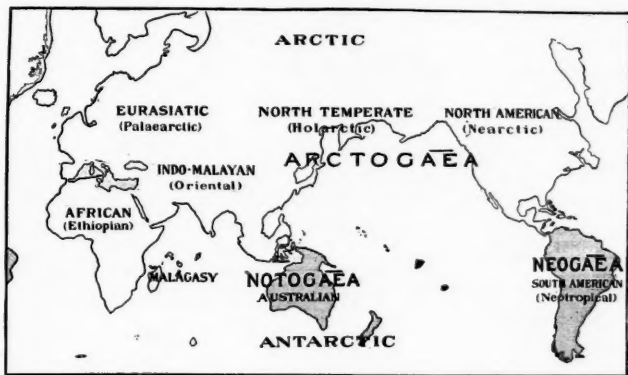


FIG. 2.— Division of the world into three realms and nine main geographical regions. The continental platform is raised to the 200 meter line showing the main Tertiary land connections. (From Osborn.)

means the exclusive areas of distribution, for during the periods of land contact certain members of these orders found their way into adjacent realms. Each realm, therefore, contains its pure autochthonous types and its migrant or derived types. REGIONS, on the other hand, may be distinguished from realms as geographical and zoölogical areas, which have been isolated from each other for shorter periods, either by climatic barriers, as in the case of the Arctic or circumpolar region, or by great physical barriers, such as masses of water and of desert sands. In certain cases these regions, such as Africa, appear to have been so large, distinct and isolated, as to have become important centers of the radiation of certain *orders* of mammals and almost attain the rank of realms, but regions in general are chiefly and permanently distinguished by the *adaptive radiation of families of mammals*.

In this paper Africa was treated hypothetically as a great center of independent evolution and as the source of successive northward migrations of animals. This hypothesis has recently been confirmed by remarkable paleontological discoveries in northern Africa. This adds to the above list of five radiations a sixth, namely:

VI. *African Radiation of Placentals*, chiefly Proboscidea; Hyracoidea; the families Antelopidæ, Giraffidæ, Hippopotamidæ, etc.

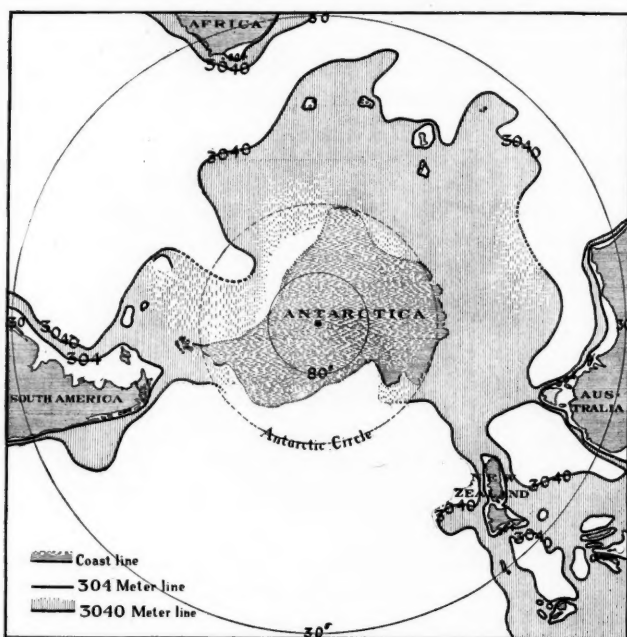


FIG. 3.—Restoration of Antarctica, a hypothetical center of Tertiary adaptive radiation, by elevation to the 3040 sounding line, showing old continental lines. (From Osborn.)

III. THE LAW OF LOCAL ADAPTIVE RADIATION AS EXHIBITED IN RELATED CONTEMPORANEOUS TYPES.

As seen in operation among the ungulates the competition and range for food originates the lengthening of limb from slow-footed into cursorial types, and the lengthening of teeth from short-crowned (brachyodont) into long-crowned (hypso-dont) types, and frequently the lengthening of skull from brachycephalic into dolichocephalic types (Osborn, '02a).

The especial application to paleontology to be noted here is that as these types may have lived together or in proximity and resorted to the same water courses for drink, their fossilized

remains are often found together. Yet if we examine analogous types living to-day, we see that they do not frequent exactly the same feeding ranges nor do they subsist upon exactly the same food; they thus do not compete. Good illustrations of this *local adaptive radiation* are seen in the distribution in Africa of the closely allied square-lipped *Rhinoceros simus* with hypsodont teeth, which lives upon grasses, and the more pointed-lipped *R. bicornis* with brachyodont teeth, which lives mainly upon shrubs. Both species belong to the same phylum of rhinoceroses. Among fossil types closely related to the above we observe similar cases, such as the coexistence in the lower Pleistocene of the hypsodont *R. antiquitatis* (woolly rhinoceros) and the brachyodont *R. hemitæchus*.

If carried farther than in the above instances, we may be justified in placing these *local adaptive radiations* in separate subfamilies, because in many cases they give rise to distinct and long-persistent collateral phyla.

Examples of this kind are numerous among the ancient Perissodactyla or ungulates related to the horses, tapirs, and rhinoceroses, as seen below.

<i>Families.</i>	I. STOUT-FOOTED, HEAVY-LIMBED PHYLUM.	II. SLENDER-FOOTED, LIGHT-LIMBED, CURSORIAL PHYLUM.
	<i>Subfamilies.</i>	<i>Subfamilies.</i>
1. Palæotheriidae	Palæotheriinae B. <sup>1</sup> (Middle Eocene to Lower Oligocene)	Palaplotheriinae (Middle Eocene to Lower Oligocene)
2. Titanotheriidae	Palæosyopinae B. (Middle Eocene to Upper Eocene)	Telmatotheriinae H. <sup>1</sup> (Middle Eocene to Upper Eocene)
3. Hyracodontidae	Hyrachyinae B. (Middle to Upper Eocene)	Triplopodinae B. (Middle to Upper Eocene)
4. Lophiodontidae	Lophiodontinae B. (Middle to Upper Eocene)	Heleletinæ B. (Eocene) Colodontinae B. (Oligocene)

It will be observed at once that there is no inherent correlation between *brachyodontism* and *brachypody*, or *hypsodontism* and *dolichopody*, or elongation of the feet, as we might have anticipated, although hypsodontism is gradually developed in

<sup>1</sup> B. = brachyodont; H. = hypsodont.

most long-footed series because subsistence upon grasses is associated with such conditions of life as are afforded by extensive open plains, long ranges for food, and rapid flight from enemies. Again, as shown elsewhere, dolichocephaly and dolichopody, brachycephaly and brachypody are frequently but not invariably correlated. (See Osborn, '02a.)

The value of this law of *local adaptive radiation* is especially great as a means of interpretation of the frequent contemporaneous existence or association of more primitive (brachyodont) with more specialized (hypsodont) types. Among Tertiary machærodont cats it is seen in the contemporary long-limbed *Dinictis* and short-limbed *Hoplophoneus*. In fact, the association has been so often observed that if we find one phylum, we may almost anticipate or predict the discovery of the other.

The law is made more clear by referring to the above table and the following explanation of it: (1) As compared with the Palæotheriinae, the Palaplotheriinae are so long-footed that Huxley believed that they gave rise to the horse, and he actually placed *Paloplotherium minus* as the ancestor of the horse series. (2) The Telmatotheriinae are large animals also distinguished by very long, slender limbs; they independently acquired horns, and the species *T. cornutum* was believed by Osborn to be ancestral to the titanotheres; but as a matter of fact, as shown by Earle and Hatcher, this horn is a pure case of parallelism, since the titanotheres probably sprang from the short-skulled and relatively stout species, *Palæosyops mantoceras*, a member of the Palæosyopinae. (3) The Triplopodinae present the most extreme instance of light-limbed development among the perissodactyl ungulates, since the limbs have the proportions of some of the most slender and swift-footed ruminant mammals, although these animals are found in the same beds with the correlated subfamily Hyrachyinae. (4) Among the Lophiodontidae, the Helaletinæ bring out with additional force the principle that this elongation of limb occurred at a very early geological period; because the first known member of this phylum appears way down in the Lower Eocene, Wasatch, or Suessonian beds, in the genus *Heptodon* Cope, a remarkably light-limbed form, and it runs right through,

so far as we know, into the Oligocene genus *Colodon*, the three-toed type with extraordinarily elongate digits. So far as we know, this light-limbed series is found both in America and Europe, while the heavy-limbed *Lophiodontinæ* are found only in Europe.

Since the above was written the titanotheres have been more carefully examined by the writer (Osborn, '02b), and, like the rhinoceroses, they are found to subdivide into four contemporaneous phyla distinguished chiefly by dolichocephaly and brachycephaly and by relatively long and short limbs, thus affording another conspicuous illustration of this *law of local adaptive radiation*.

#### IV. RADIATION AND CORRELATION OF STRUCTURE.

In the careful consideration of adaptive radiation from certain stem types is to be found the true significance of Cuvier's *law of correlation* as modified by the — to him — unknown principle of evolution. Referring to the diagrams, Fig. 4, two important principles are brought out: First, practically all the adaptations known among mammals have arisen by combinations of divergence independently pursued in the limbs and teeth; for example, an herbivorous tooth type may combine with a terrestrial, arboreal, or volant limb type, according as the search for plant food is on the earth, in the trees, or in the air. Although every imaginable combination (*e.g.*, aquatic limbs, myrmecophagous dentition) cannot be realized, yet these combinations have been multiplied almost *ad infinitum* and constitute the fatal defect of Cuvier's law as he conceived it. As tested by a single case, the Eocene monkeys of the family Notharctidæ acquired teeth exactly homoplastic with those of Eocene horses, but the former were provided with arboreal, the latter with terrestrial, limb types. Second, correlation of limb and tooth structure in a given group is further conditioned by the particular combination and degree of specialization of limbs and teeth which the radiation originates with. For example, the primitive placentals combined tritubercular insectivorous teeth with a generalized or probably terrestrial

type of feet; the Australian marsupial radiation, on the other hand, began with a dental type similar to that of the placentals,

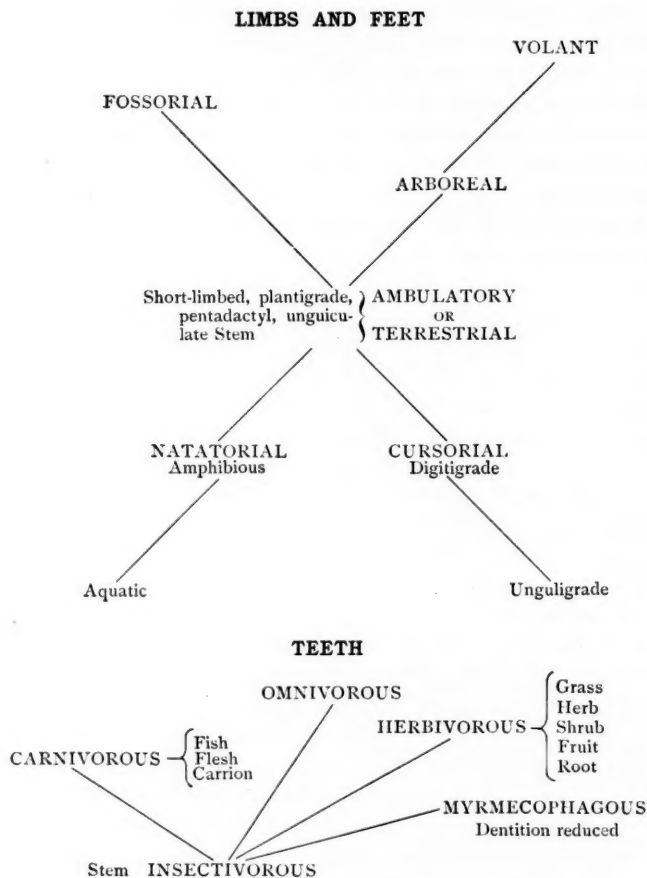


FIG. 4.—Main lines of adaptive radiation of (a) limbs and feet, (b) teeth among mammals.

but, as Dollo and Bensley have shown, the foot type was of highly specialized arboreal character.

These two fundamental exceptions make clear why it is impossible, as many writers have observed, to reconstruct an

entire animal from either a claw or a tooth. Thus, while the law of correlation is no less dominant than Cuvier supposed, only a vestige is left of the mode of archetypal operation of the law as he conceived it. It may be now restated as follows: Feet (correlated chiefly with limb and body structure) and teeth (correlated chiefly with skull and neck structure) diverge independently in adaptation respectively to securing and eating food under different conditions. Each evolves directly for its own mechanical functions or purposes, yet in such a manner that each subserves the other.

Correlation is therefore not morphological, as Cuvier supposed, but physiological, function always preceding structure. It becomes closest where teeth and feet combine in the same function as in the prehensile canines and claws of the Felidæ, and most diverse where the functions are most diverse, as in the teeth and paddles of the Pinnipedia.

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## NEW AND LITTLE-KNOWN GUESTS OF THE TEXAN LEGIONARY ANTS.<sup>1</sup>

CHARLES THOMAS BRUES.

THE species included in the present paper are all Ecitophiles which have been collected in the vicinity of Austin, Texas, by Dr. Wm. M. Wheeler, Mr. A. L. Melander, and the author, during the past two winters. The three species of *Eciton* (*E. schmitti* Em., *E. opacithorax* Em., and *E. cæcum* Latr.) which occur here commonly seem to harbor a larger number and a greater range of myrmecophiles than any other restricted group of ants with which we are acquainted. Their nest mates seem also to be more aberrant forms than those living with the other ants,—a condition which may possibly be produced by two unusual peculiarities of the Ecitons. Their eyes are very small (even absent in the worker of *E. cæcum*), and their power of vision must be correspondingly poor; then, too, their nomadic life must prevent many myrmecophilous forms from living with them, which would otherwise probably occur regularly. *Eciton schmitti* and *E. opacithorax* change the sites of their nests quite frequently and may often be seen marching in columns which extend over long distances, and at such times their guests must either travel along with them or be left to shift for themselves. *Eciton cæcum* is apparently always upon the move, but traveling below the surface of the ground and not venturing out, at least in the daylight.

Insects of three different orders are represented, Diptera, Hymenoptera, and Coleoptera; the new Diptera which belong to the family Phoridae being among the most peculiar and remarkable of described myrmecophiles.

<sup>1</sup> Contributions from the Zoölogical Laboratory of the University of Texas, No. 25.

## COLEOPTERA.

## CARABIDÆ.

1. *Anillus affabilis* sp. nov.

Length 2 mm. Rufotestaceous, darker anteriorly, elytra lighter than head and thorax. Head smooth, shining; frontal impressions deep but not large. Antennæ testaceous, scarcely longer than head and thorax, slightly thickened towards apex. Palpi testaceous. Thorax distinctly wider than long, widest near the anterior angles, narrowest at base. The sides arcuate anteriorly and slightly sinuate posteriorly. Surface sparsely but distinctly pubescent. Side margin very narrowly reflexed, distinctly serrate, with four or five teeth near the slightly obtuse posterior angles. Median line delicately but distinctly impressed. Posterior transverse

impression arcuate, the surface finely rugose behind it. Elytra considerably wider than thorax, distinctly serrate at the broadly rounded humeral angles and posteriorly to middle, where the teeth become obsolete. Side margin regularly arcuate, not at all angulated. A row of large punctures near the lateral margin, growing smaller and less distinct toward the apex, form an ill-defined, broad lateral stria. Dorsal striæ almost obsolete, the first three very faintly impressed, remainder indistinguishable. Elytra with three long lateral setæ, one at humeral angle, one at posterior third, and one subapical. Just anterior to the first long seta is a shorter one. Elytra sparsely clothed with erect pubescence. Legs pale testaceous.

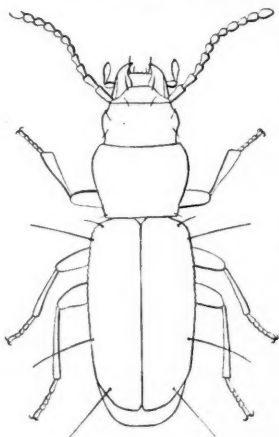


FIG. 1. — *Anillus affabilis* sp. nov.

Described from three specimens collected at Austin, Texas. Two were sifted from a nest of *Eciton cæcum* Latr., and one from a nest of *Solenopsis geminata* Fabr. While *A. affabilis* may not be strictly myrmecophilous, it is evidently partial to ant nests as a habitation.

This species most closely resembles *A. explanatus* Horn, from which it differs in having broadly rounded humeral angles, no angulation of the elytral margin, and by the three large elytral setæ.

The Californian *A. debilis* Lec. has been recorded from Texas by Schwarz, but the species here described differs in having the elytra serrate near the humeri. The original three-line description of *A. debilis* Lec.<sup>1</sup> would not serve for identification, but Horn<sup>2</sup> mentions that the elytra have the "margin not serrate."

## STAPHYLINIDÆ.

2. *Ecitonidia wheeleri* Wasmann.<sup>3</sup>

A second specimen of this species was found April 20, 1901, in a nest of *Eciton schmitti* Em., the same species with which the type specimen was discovered. It is nearly as large as the worker ants and quite similar in color and movements, so that it is rather difficult to distinguish among a large number of ants. It is undoubtedly mimetic of the ants, but whether its resemblance enables it to deceive the ants as to its identity would seem very doubtful. The probability of its resemblance being due to some outside influence of natural selection is heightened by the fact that it must be exposed to insectivorous animals as it marches along in the columns of the ants, which are often seen in broad daylight and hence are exposed more than most species of ants with their attendant myrmecophiles.

3. *Ecitopora tenella* Wasmann.<sup>4</sup>

The original types of this species were part of a collection of numerous specimens from a nest of *Eciton schmitti* collected during October at Austin. Since that time we have found another species of this genus, the second to be recorded from North America.

*North American Species of Ecitopora.*

Thorax one and one-half times as wide as long, strongly arcuate on the sides, length 3 mm. . . . . *laticollis* sp. nov.  
Thorax but slightly wider than long, almost straight on the sides, length 2-2.3 mm. . . . . *tenella* Wasm.

<sup>1</sup> *Trans. Amer. Phil. Soc.*, vol. x, N.S., p. 397.<sup>2</sup> *Trans. Amer. Ent. Soc.*, vol. xv, p. 26.<sup>4</sup> *Loc. cit.*<sup>3</sup> *Neue Dorylinengäste, Zool. Jahrb.*, Abth. f. Systematik, Bd. xiv, Heft 3, p. 69.

4. *Ecitopora laticollis* sp. nov.

Length 3 mm. Pale fuscous; head black, elytra almost testaceous, thorax somewhat darker on the disk. First two abdominal segments with a lighter band at apex, abdomen elsewhere fuscous, legs alutaceous. Antennæ fuscous, paler on three basal joints; beyond the third joint they are very gradually thickened toward the tips, joints 4-10 being not quite twice as wide as long. Eleventh joint conical, slightly longer than the two preceding. Thorax one and one-half times as wide as head and one and one-half times as wide as long; widest at the middle, before which it is rather sharply narrowed; behind it is not so strongly narrowed. Front margin of the thorax somewhat concave on each side of the middle. Elytra not wider than the thorax at their base. Abdomen at base as wide as the prothorax, acuminate.

This species resembles *E. tenella* in general color and appearance, but is larger, with darker head and much wider thorax.

Described from numerous specimens collected in a nest of *Eciton schmitti*, February, 1901.

## HISTERIDÆ.

5. *Ulkeus intricatus* Horn.<sup>1</sup>

Two specimens of this remarkable histerid were collected in a nest of *Eciton opacithorax* Em., March 24, 1901. They agree very well with Horn's original description, except that the frontal carinæ are divergent, not convergent above, and the network of fine raised lines upon the discal portion of the thorax is very faintly outlined in some places.

Horn makes no mention of the peculiar structure of the setæ with which the body is clothed. All the hairs upon the body are provided with long barbs. Those upon the head have the barbs shortest and scattered upon the central spine, but easily distinguished from it. Those upon the remainder of the body have no distinct central spine except at base, beyond which they split up into about five or six sharp barbs. Upon the dorsal surface of the body each forms a sort of stiff brush, which is flattened so as to appear very slender when seen from the side, but quite spreading when viewed from the front.

<sup>1</sup> *Trans. Amer. Ent. Soc.*, vol. xii (1885), pp. 142-143.

There can be no doubt that this histerid is a true myrmecophile of *Eciton opacithorax* Em., for Wasmann mentions it as occurring in North Carolina near a nest of the same ant.<sup>1</sup>

6. *Echinodes setiger* Lec.

We have found this histerid in company with *Eciton cæcum*, although very rarely. It is not uncommonly seen, however, in nests of *Solenopsis geminata* Fabr. and various species of Pheidole.

HYMENOPTERA.

PROCTOTRUPIDÆ.

7. *Ceraphron croceipes* sp. nov.

Female. Length 1 mm. Black, shining, feebly punctured. Antennæ ten-jointed, black, scape ferruginous except at tip, where it is darker; pedicel pale at tip, constricted towards base, one and one-half times as long as first flagellar joint; second joint as long as first but stouter, not transverse; 3-5 equal in length, but gradually wider; 6 and 7 broadest, subequal, quadrate; last joint as long as two preceding, and as wide at base, acutely conically pointed at tip. Head finely punctured and white pubescent. Frontal cavity deep, circular in outline, bare, and impunctured. Groove in front of anterior ocellus punctiform. Mandibles dark yellow, palpi pale. Collar black, with a lemon-yellow stripe on each side. Thorax very delicately punctulate and white pubescent; mesonotum with a small tooth at each anterior angle. Axillæ broadly meeting in front of the scutellum, which is one-half longer than wide and fringed with stout golden bristles on the sides, except near the apex, its sides strongly areolated anteriorly. Postscutellum rounded at tip, its sides sinuate and white pubescent. Metathorax polished, its posterior angles produced and carinate. Metapleuræ smooth, obliquely striolate behind, and bounded by two carinæ above. Tegulæ piceous, wings subhyaline, slightly infuscated toward apex. Abdomen polished black, the second segment twice as long as the following segments, coarsely striolate at base, with a tuft of white pubescence at each anterior angle. Third and fourth segments about equal, fifth and sixth shorter and equal. Legs, including coxæ, wholly deep yellow, except the apical joint of all the tarsi, which is piceous. Posterior coxæ with a bunch of yellow hairs posteriorly.

Described from a female specimen collected in the galleries of a nest of *Eciton cæcum* Latr., at Austin, Texas, Feb. 3, 1901.

<sup>1</sup> Ein neuer Eciton-Gast aus Nord-Carolina, *Deut. Ent. Zeit.*, Heft 2 (1897), p. 281.

This species is quite closely allied to *C. pedalis*, *flaviscapus*, *glaber*, and *carinatus*, but is distinct from all by the form of the antennæ, axillæ, postscutellum, and maculation of collar.

**Ecitonetes gen. nov.**

Head globose, with a deep longitudinal frontal depression. Ocelli in a triangle, small and close together. Eyes oval, one-half as long as head and one-half as wide as long, coarsely faceted. Antennæ inserted on pro-

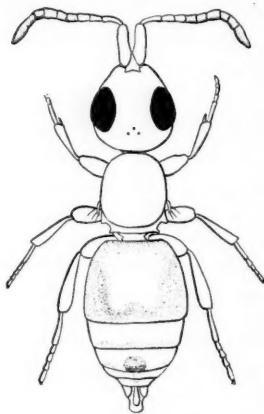


FIG. 2.—*Ecitonetes subapterus* ♀  
sp. nov.

jections near the base of the clypeus; ten-jointed in female, scape stout, one and one-half times as long as eye, pedicel one-half longer than first flagellar joint, slender. Antennæ thickest at the seventh joint; last joint about one-third as long as scape and obtusely pointed at tip, equal in length to pedicel. Maxillary palpi long, four-jointed, last joint somewhat swollen; mandibles indistinctly bidentate. Thorax oval, the prothorax not visible from above. Mesonotum oval, rounded before and behind, considerably narrower than the head, and without any furrows or grooves. Scutellum absent, or at least not separated from that part of the mesonotum which extends over the place usually occupied by the scutellum. Metathorax produced into small teeth on extreme lateral and latero-

posterior angles; much reduced, sloping on the sides and narrowed behind. Wings very small, about as long as distance between posterior ocelli or length of third antennal joint, with a strong vein along the costal margin and three strong bristles on the apical front margin, each about as long as the wing. Abdominal petiole very short, the abdomen squarely truncate at the base, where it is about as wide as the thorax. Abdomen oval, acuminate, with six visible segments, the first of which is as long as the rest together, second and third subequal, each about one-fourth as long as first. Legs rather short, stout; femora, especially posterior pair, swollen; anterior and posterior tibial spurs well developed. First joint of all tarsi elongated and longer than the three following; claws simple.

**8. *Ecitonetes subapterus* sp. nov.**

Length 2 mm. Light ferruginous, except the apical three joints of the antennæ, which are black; a sinuous dark band on the first abdominal segment, lighter toward the sides and hind margin; the narrow posterior margins

of second and third segments, and an oval spot on the third segment, dark. Eyes but little convex, finely hairy. Ocelli almost equidistant, small, and rather close together. Basal half of antennæ lighter than body, almost yellow. Thorax convex above, somewhat darker than the head. Abdomen smooth, without striæ or grooves, convex above and rather sharply convex below, so that the median line is quite sharply defined. Ovipositor black.

Described from one female specimen, collected in a nest of *Eciton cæcum* Latr., at Austin, Texas, during February, 1901.

While searching for the myrmecophilous Phoridæ in the nests of the large blind driver ant I chanced upon this small insect, which, from its actions and color, simulated one of the very smallest of the *Eciton* workers. Had it not been for its exceedingly small size and more robust build it would undoubtedly have passed unobserved

among the ants. On examination with a lens, however, it was easily recognized as a proctotrupid. I have been unable to refer it to any described genus, although its place in the Ceraphronidæ is quite certain.

It seems most closely related to *Lagynodes* Först., from which it differs by the ten-jointed antennæ, shorter scape, distinct ocelli, absence of groove on mesonotum, absence of scutellum, and shorter legs. The dark spot upon the third abdominal segment when strongly magnified is seen to consist of a network of raised black lines, which are coarser and more distinct posteriorly. This structure is interesting, as we know that at the same relative position on the abdomen of other *Eciton* myrmecophiles (Phoridæ) we also find a spot where the integument is peculiarly modified. This suggests some possible way that these blind ants may have of recognizing their habitual nest mates by means of markings which they can perceive by touch.

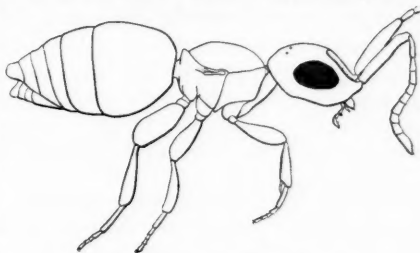


FIG. 3. — *Ecitonetes subapterus* ♀ sp. nov.

9. *Telenomus texanus* sp. nov.

Female. Length 1 mm. Black, shining, smooth, except thorax, which is very finely punctured. Antennæ piceous, lighter at base and apex of scape and apex of pedicel. Mandibles yellowish at tips. Head but little more than twice as wide as long antero-posteriorly, sparsely white pubescent. Face shining, smooth, vertex distinctly reticulate with fine impressed lines, reticulation extending down for some distance along the inner border of the eye. Front ocellus in a depression, lateral ones contiguous with eye margin. Eyes black, sparsely covered with short white hairs. Antennæ eleven-jointed; pedicel one and one-half times as long as first flagellar joint, which is nearly twice as long as thick; second and third thicker, but of same length as first; fourth small, transversely oval; fifth larger, transverse; three basal joints of club nearly equal, subquadrate; last joint conical. Thorax as wide as head, more thickly and finely hairy, and not so shining. It is also reticulate, but less noticeably than the head. Wings fusco-hyaline, marginal vein three-fourths as long as stigmal, wing margins strongly fringed. Abdomen very shining, slightly longer than thorax; second segment about as wide as long; the apical three segments fringed with fine white bristles. Legs and coxæ deep yellow; hind femora infuscated on middle portion, tibiæ, also, to a less degree. Tarsi paler, except last joint, which is black.

Described from a female specimen collected in a nest of *Eciton cæcum* Latr., near Austin, Texas, during March, 1901. The insect was found among the ants at a distance of several inches below the surface of the ground.

As all the other members of this genus are egg parasites it is possible that this species may be parasitic upon some guest of the *Eciton*, as is sometimes the case.

*Telenomus texanus* is most closely related to *T. geometræ* and *T. noctuæ*, from either of which it is easily distinguished by the form of the head, antennæ, and marginal vein.

10. *Phænopria acutiventris* sp. nov.

Female. Length 1 mm. Black, shining, impunctured. Antennæ rufo-piceous, the three-jointed club piceous; scape slender, arcuate; pedicel stout, oval, equal in length to first joint of club. First joint of flagellum one and one-half times as long as the second, which is moniliform, third and following joints increasing in size, moniliform except the last, which is oval and as long as the two preceding taken together. Posterior margin of head and anterior margin of collar white pubescent. Mesonotum considerably narrowed in front, convex. Scutellum flat at base and strongly convex on



the disk, without any pits or grooves. Wings hyaline, reaching considerably beyond the tip of abdomen, strongly fringed. Metathorax pubescent, dark rufous. Petiole and all the coxæ and trochanters saturate yellow, the former white pubescent. Femora and tibiæ strongly clavate, the swollen part piceous, becoming concolorous with the coxæ at the bases; tarsi slender, fuscous, darker at the tips. Abdomen highly polished, as long as head and thorax together, and conically pointed at the tip. Second segment reaching to a little beyond the middle of abdomen; third and fourth segments very short; fifth long and pointed, beset with a few stout white hairs.

Described from a female specimen collected in a nest of *Eciton cæcum* Latr., near Austin, Texas, during March, 1901.

I have placed this species in the genus *Phænopria* because of the form of the scutellum, although it resembles species of the genus *Tropidopria* in the form of the abdomen.

#### PHORIDÆ.

##### *Acontistoptera* gen. nov.

Head very broad, more than one and one-half times as wide as thorax at widest portion, widest at the front angles; half as long as wide; seen from above regularly arcuate in front, concave behind; front angles sharp, hind ones broadly rounded. Epistoma projecting slightly and visible from above as a narrow band extending between the antennæ. Eyes smaller than in *Ecitomyia*, oval, their longest axis equal to diameter of large antennal joint. Upper surface of head with a pair of small median macrochætæ, eight marginal ones on lateral and posterior edges, one over each eye, a bunch at front angles, and a regular series of closely placed ones along the front between the antennæ. Antennæ of the usual form, with an apical arista. Palpi projecting, of the usual form. Head seen from the side higher than long; front long, but slightly descending, rather acutely prolonged over the deep antennal cavity. Mentum very large, bristly along the front margin, and bearing several discal macrochætæ. Eyes very small, contiguous with front margin of the head below the middle of the antennal cavity; ommatidia hemispherical, few in number. Sides of head with a few macrochætæ below and behind the eye and a series of marginal ones from front edge to middle of lower margin.

Thorax small; when seen from above, much narrower than the head and greatly narrowed behind, the sides slightly sinuate; about one and one-third times as long as the head. The pleuræ partially visible from above, owing to the narrowness of the dorsum. Dorsum with a pair of very long, stout macrochætæ at the anterior angles and a shorter pair directly posterior to these. A pair of anterior, closely approximated, small discal macrochætæ;

two median larger and less approximate ones; and a pair of subapical ones. Scutellum very small, with a pair of dorsal macrochaetae. Thorax, seen from the side, but little larger than the head, strongly elevated in front;

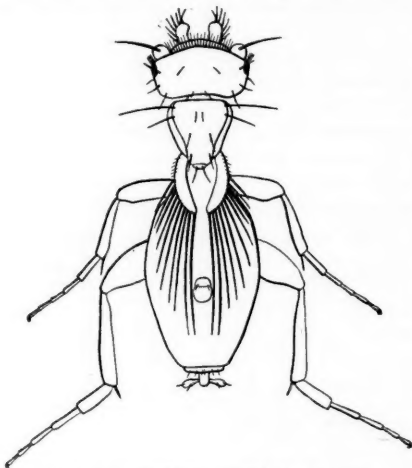


FIG. 4.—*Acontistoptera melanderi* ♀ sp. nov.

coxae of the usual form. Legs rather slender, especially the tarsi. Spurs of four front tibiae well developed. Wings about as long as the width of the thorax, arcuate, of nearly equal width and obtuse at tip, with a few short marginal bristles on its basal external margin. At about the middle these suddenly enlarge to form enormous macrochaetae, which continue to enlarge until at the tip they are more than twice as long as the wing and exceedingly stout. There are about ten of these large macrochaetae, which are all strongly, thickly, and almost scaly pubescent. Abdomen shaped as in *Commoptera*, without any indications of segments or sclerites, except the one probably corresponding to the fourth dorsal plate of *Ecitomyia*, which is small, with two macrochaetae, and has a chitinous ring extending from its posterior edge, which no doubt serves in connection with a gland like that of *Ecitomyia*. Abdomen everywhere sparsely and regularly finely bristly.

#### 11. *Acontistoptera melanderi* sp. nov.

Length 1 mm.; of longest wing bristle, .4 mm. Light yellow, head darker, fuscous in places, the occiput irregularly lighter, a small yellow circular spot at the base of all the macrochaetae. Antennae and palpi and lower part of the head yellowish white. Thorax above but little lighter than head. Wings almost white, their bristles black and very conspicuous. Abdomen, underside of thorax, and legs pale yellow. Legs finely black hairy and more deeply colored distally.

Described from a single female specimen<sup>1</sup> collected in a nest of *Eciton opacithorax* Em., March 24, 1901, at Austin, Texas.

<sup>1</sup> After this article had gone to press we were so fortunate as to find ten more female specimens in another nest of the same ant on December 6 and 7, 1901. They differ in no respect from the example figured, except that the abdomen is in

On overturning a large stone, beneath which a small colony of the ants had formed their nest, the fly in question was seen darting about upon the surface of the ground in the exceedingly nervous manner which characterizes the movement of *Ecitomyia*. It appeared much larger than any specimens of *Ecitomyia*, but, unfortunately, in capturing it the abdomen collapsed so that it has been impossible to determine whether the large size was due simply to a swollen condition of the abdomen or to something attached to it (possibly one of the very large eggs or a larva).

This form is at once recognized by the marginal row of enormous macrochætæ on the wings, which are also broader than those of *Ecitomyia*. The head is exceedingly large and wide in comparison with the extremely narrow thorax, which is quite different from that of any described phorid, in that the dorsum is so narrow that it allows the pleuræ to be visible from above along their entire length. The head is very much flattened and is remarkable for the row of closely placed macrochætæ along the anterior edge of the front. The eyes are about the size of those of *Ecitomyia* and have the same degenerate external structure. The mentum is large and more closely continuous with the sides of the head than is usually the case. The abdomen is wholly membranous, with the exception of a single segment (the fourth?), which lies directly anterior to the abdominal gland instead of behind it as in *Ecitomyia*; a rather remarkable difference were it not known that in

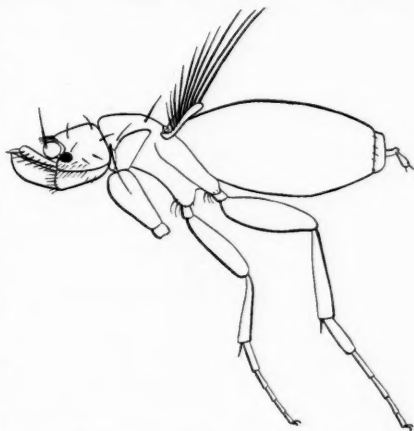


FIG. 5.—*Acontistoptera melanderi* ♀ sp. nov.

some cases nearly twice as large, swollen out and filled with a liquid in which can be seen large developing eggs, some of which have the blastoderm completely formed.

another Texan genus, *Commoptera*, the gland is situated in the middle of the segment and could thus give rise independently to the condition of *Ecitomyia* or to that of *Acontistoptera*. The legs of this form are long and quite slender, the front ones are unfortunately broken off at the base of the femur in the only specimen I possess.

***Xanionotum* gen. nov.**

Head broad, one and one-half times as wide as the dorsum of the thorax near the posterior angles; rounded triangular in shape, the anterior angles not at all evident, posterior ones rounded; twice as wide as long antero-posteriorly, when seen from above. Eyes barely visible from above at the

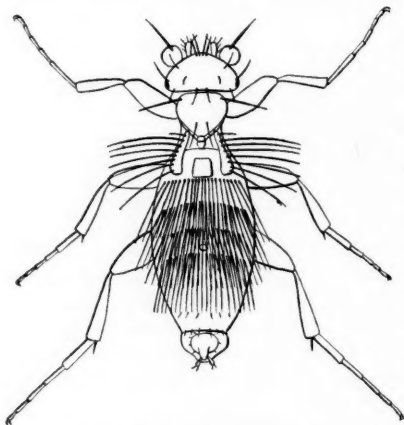


FIG. 6. — *Xanionotum hystrix* ♀ sp. nov.

extreme posterior angles of the head. Four marginal macrochaetae on middle of front, one on each side half-way toward the eye, another just in front of eye, one at posterior angle, and a pair of median posterior marginal ones and two widely separated discal ones. Antennae rather large, of the usual form with apica arista, attached at the lower part of their unusually shallow cavities. Palpi visible from above for a distance equal to diameter of second antennal joint, rather slender, and with the usual bristles. Epistoma

not visible from above. Ocelli absent. Eyes very small, situated slightly below and in front of the center of the sides of the head. Cheeks bristly, bearing a marginal row and an exceptionally strong macrochaeta at the lower posterior angle. Proboscis nearly as long as height of head, acuminate, slightly geniculate at base. Thorax rounded, rather suddenly narrowed behind, much narrower than the head and a little longer; slightly wider than long. It is very broadly rounded on the sides and at the anterior angles, and not at all sinuate on the sides. Dorsum so wide as to almost entirely conceal the pleurae. Scutellum very small, without macrochaetae. Metathorax visible behind it as a sclerite, which is but little larger than the scutellum. Dorsum with a pair of strong macrochaetae on the anterior angles, which are as long as the greatest width of the thorax; also a pair of strong postmedian

discal ones. Thorax seen from the side considerably larger than the head, the dorsum regularly arcuate. Coxæ as usual, the anterior ones rather short; legs slender, the tarsi long, spurs of four posterior tibiæ well developed. Wings nearly as long as width of thorax, clavate, about two-thirds as wide at base as at apex, where they are rounded truncate. Wings very strongly bristly, the macrochaetæ longer than the wing, the longest being one and one-half times as long, much more slender than those on the wings of *Acontistoptera*. All the bristles are on the distal three-fourths of the outer margin, about seven on the upper edge and three or four below. Abdomen of the usual shape with the dorsal plate of only the fourth segment visible; it is quadrate, somewhat narrowed in front and about as wide as diameter of second antennal joint. The gland opening on the fourth segment small and with the margin hardly at all thickened. The posterior margin of the four anterior abdominal segments marked off by wide rows of enormous macrochaetæ which extend more than halfway across the abdomen. Each row contains about twenty bristles, those in the anterior rows being somewhat the longest and nearly equaling the wing bristles in length and thickness. Each bristle is not simple but composed of two distinct pieces, a short, stout basal piece, apparently contiguous with the abdominal cuticle and hollowed out into a spoon-shaped dorsal cavity at the apex into which the bristle is articulated. Fifth, sixth, and seventh segments faintly indicated by marginal bristles and by constrictions. Abdomen everywhere sparsely short hairy. Sexual organs smaller than usual.

#### 12. *Xanionotum hystrix* sp. nov.

Length 1.25 mm. Light yellow, almost white, the head much darker above, except an irregular yellowish spot on the vertex; all the large macrochaetæ fuscous. Thorax tinged, darker above, especially in front. Legs concolorous with the body, tarsi darker yellow, legs finely black hairy.

Described from a single female specimen<sup>1</sup> collected at Austin, Texas, March 24, 1901, in the same nest of *Eciton opacithorax* in which the specimen of *Acontistoptera melanderi* was discovered. Although the nest was carefully sifted it revealed no other specimens of either form.

This form is undoubtedly the most remarkable phorid which we have collected here, and although it was so closely associated with the other new genus here described, there seems to be no possibility of considering them as dimorphic forms of a single species, as almost every part of the body is quite different in

<sup>1</sup> We have since found another exactly similar specimen with the same ant. December 6, 1901.

structure. It has been placed in a different genus on account of the different shape and chaetotaxy of the head, its shorter thorax with broader dorsum, abdomen with first dorsal plate present and fourth wanting, and with the four rows of large spines. We must of course expect to find a greater disparity between these greatly degenerate forms than among more specialized Diptera, but to include two such dissimilar species in the same

genus is hardly consistent with the importance usually laid upon structural characters.

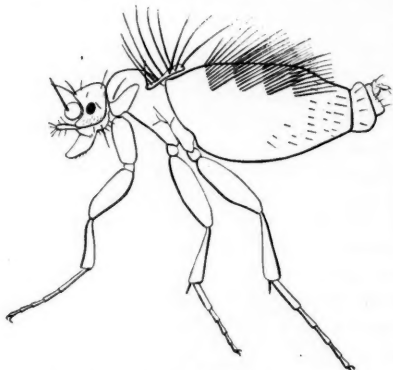


FIG. 7.—*Xanionotum hystrix* ♀ sp. nov.

The head is very strongly arcuate in front and the lower margin is not visible from above. The antennae are larger than in the other genus, and the eyes slightly smaller. The thorax is not so unusual in shape, although the pleurae are

slightly visible from above on the posterior part. The thorax in both genera is, however, a closer approach to the typical dipteran thorax than that of *Ecitomyia*. The rows of closely placed abdominal spines are an unusual development, which give the abdomen a most peculiar appearance. In this form the opening of the abdominal gland is near the middle of the fourth segment.

### 13. *Ecitomyia wheeleri* Brues.<sup>1</sup>

This form is an habitual nest mate in most of the *Eciton cæcum* nests which we have seen in this region, although the imagines become rare and perhaps disappear entirely upon the approach of the summer heat and drought.

The two specimens from a nest of *Eciton schmitti* Em. may possibly have represented another closely allied species, but were unfortunately sectioned before it was recognized that numerous species of myrmecophilous Phoridae occur in this region.

<sup>1</sup> *American Naturalist*, May, 1901.

## ON THE STRUCTURE AND CLASSIFICATION OF THE TREMATASPIDÆ.<sup>1</sup>

WILLIAM PATTEN.

OF all the families usually included in the problematical and heterogeneous group of animals called the "ostracoderms," none is more interesting to the morphologist than the Tremataspidae, as the little known about them shows they possessed a most extraordinary structure, unlike in many respects that of any other group of animals. While the character of the trunk scales, of the orbits and other sensory openings, the minute structure of the shell, and the presence of the newly discovered lateral-line system clearly indicate the affinity of Tremataspis with Pteraspis, Cephalaspis, and Pterichthys, and through them with the true vertebrates, other features, such as the general shape of the shield and its more superficial texture, which have long been a source of perplexity to the paleontologist, clearly point to the affinity of Tremataspis with arthropods like Limulus, Apus, and the trilobites.

The importance of the Tremataspidae to the morphologist also lies in the fact that while the specimens are rare and more or less fragmentary, they are usually well preserved and give fair promise that ultimately we shall be able to decipher in detail the structure of all their hard parts. This knowledge will certainly throw much light on the morphology of the whole group of ostracoderms, and may afford decisive evidence of the genetic relationship between the vertebrates and invertebrates.

When, therefore, through the generosity of the administration of Dartmouth College, I was granted a half-year's leave of absence, I decided to make as thorough an investigation of the ostracoderms as my time and means would allow, with the special object of determining whether any evidence could be

<sup>1</sup> This paper is an abstract of one about to be published in the *Memoirs of the Imperial Academy of Sciences of St. Petersburg*.

found bearing out our assumption that they are an intermediate group of animals related on one hand with the arthropods and on the other with the vertebrates. My plan was to study all the most important collections in Great Britain and the Continent and to purchase or collect material that might be used for detailed study by sectioning or by other methods, as the

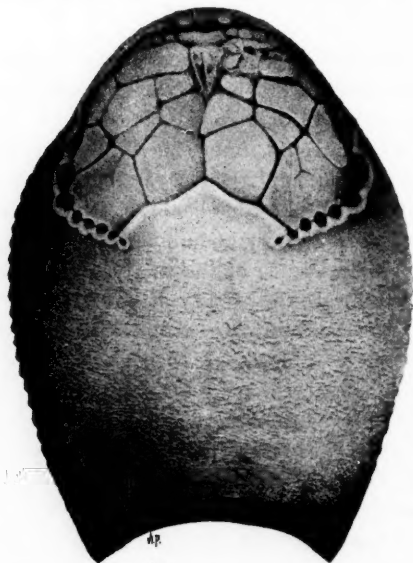


FIG. 1. — A partial reconstruction of the ventral side of the head of *Tremataspis*. Enlarged about  $2\frac{1}{2}$  diameters. The figure was made from a wax model constructed after several specimens and fragments in the University and the Imperial Academy, at St. Petersburg, and in the Dartmouth College Collections.

valuable type specimens permanently preserved in museums could not be utilized in this manner.

It did not take long to discover that the following out of the second part of my program, the collection of *Thyestes* and of *Tremataspis*, was a most difficult task. So far as I know, every fragment of these two genera has been taken from a shallow pit about four feet deep and covering perhaps an area of three or four hundred square yards, hidden in the heart of the remote and otherwise little-known island of Ösel in the Baltic Sea.



The mysterious treasures of this classic spot have drawn to its sides many famous scientific men from all quarters of the globe. From time to time during the last forty years or more many beautifully preserved eurypterids and an occasional Tremataspis have been taken from this insignificant pit in a pasture. During the past twelve or thirteen years the spot has been

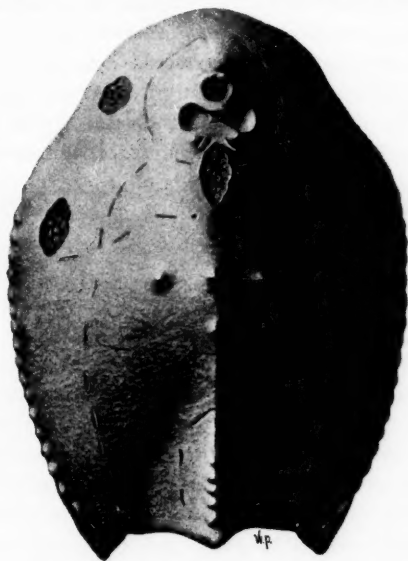


FIG. 2. — The dorsal surface of the head of Tremataspis.

worked more systematically by Mr. A. Simonson, who has collected, with very few exceptions, all the material of Tremataspis and Thyestes that has ever been found; and yet, with the most careful and painstaking work, and with considerable assistance from common laborers, two or three, very rarely four, fragmentary heads of Tremataspis are all that reward the labors of a whole summer. I considered myself fortunate, therefore, in being able to purchase nearly all of the fossils collected by Herr Simonson during that season. The collection contained many specimens of Thyestes, Cephalaspis, and Bunodes, together with four heads of Tremataspis, some of which were in exceptionally

good condition; but, unfortunately, none of the last-named genus showed the presence of the plates in the oral region.

All of these specimens have been added to the collections in Butterfield Museum of Dartmouth College.

The four heads of *Tremataspis* (which have been cleaned with great care) have enabled me to make out several new details concerning the sensory openings on the dorsal surface; they were the first to show the system of lateral-line pits, although these pits were afterwards seen on most of the St. Petersburg specimens. But they were of special value in that they enabled me to work out the structure of the anterior margin of the dorsal shield and to discover three new openings



FIG. 3. — Head of *Tremataspis* seen from the side.

in the series of so-called gill openings described by Rohon. These parts in the Petersburg material were absent or had been destroyed by rough handling.

The reconstruction of the oral region was made from a study of the single specimen and its cast that have already been described by Rohon. The original fossil had lost many details through repeated handling and the apparently incautious attempts to clean out the matrix between the edges of the plates. The original mold, however, was in nearly perfect condition, and by taking several impressions of it in dentist's wax a beautiful reproduction of the original untouched fossil was obtained, from which were worked out all the details in the arrangement of the oral plates shown in the restoration. These casts and the enlarged model are now preserved in Butterfield Museum at Dartmouth College.

Our observations on the structure of *Tremataspis* have brought out the following principal facts:

The *Lateral-Line Organs* of *Tremataspis* consist of a series of shallow groove-like dots and dashes, arranged in linear series on the dorsal surface of the shield. We distinguish a

circumorbital, marginal, anterior transverse, and a posterior dorsal line. The first two lines appear to correspond with the circumorbital, and the trunk line of *Pterichthys*. The circumorbital line is represented in *Tolypaspis* by a V-shaped ridge.

*The Sensory Openings of the Dorsal Shield.*—There are four centrally placed openings and two pairs of marginal ones on the dorsal shield of *Tremataspis*. Interpret these openings provisionally as follows: the posterior central opening is that of an olfactory organ; the three anterior central ones belong to the median eye; the anterior lateral openings contain the lateral eyes, and the posterior lateral pair, a segmental sense organ comparable with the dorsal organ of embryo *Limuli*.

The olfactory opening and both pairs of lateral openings in all well-preserved specimens possess sharply scalloped margins and a reticulated bony floor. Transverse sections show that the floor is an extension of the inner layers of the shell.

In transverse sections through the frontal depression the median slit is seen to be a true perforation of the shell, its infolded margins forming a short flattened tube.

The median orbits are separate, nearly spherical chambers, enclosed in a network of bony tissue formed by ingrowths of the inner layers of the shell. The narrow median canal that appears to connect the two orbits is closed by a deep-lying bony floor, also formed from the inner layers of the shell.

The *lateral eyes* were small and subordinate in function to the median ones. They probably occupied the anterior pair of marginal openings, the rounded incisions on the edge of the openings possibly indicating the presence of compound eyes, consisting of a few large ommatidia. The lateral eye orbits agree with those of *Limulus* in being shut off from the interior of the head by a bony network arising from the inner layer of the shell.

The *posterior marginal openings* agree in position with the so-called dorsal organs of *Limulus*, a pair of segmental sense organs serially homologous with the lateral eyes and lying in larval *Limuli* opposite the fourth pair of thoracic appendages.

*The Median Eye.*—The three anterior median openings I have compared with the triocular median eye of *Limulus*, Apus,

trilobites, Merostomata, and other arthropods, but not with the three frontal ocelli of adult insects. In *Limulus*, where the structure and development of this organ is best known, the retinas of the median ocelli arise from two pairs of segmental sense organs, that during the closing in of the brain migrate from the margins of the cephalic lobes to the roof of the fore-brain vesicle. Here the ocelli come to lie at the blind end of a long tubular outgrowth of the brain roof. The distal end of the tube then divides into two vesicles, lying in the median line, one in front of the other. The united retinas of one pair of ocelli form one of the vesicles and, at a considerably later period, lie in a degenerate condition, deeply buried beneath a median tubercle on the dorsal surface of the head. The other two retinas lie close together in the second vesicle, beneath two median lenses. These two terminal vesicles are found in a more or less modified form in many Crustacea and without doubt in the trilobites and Merostomata also, since the arrangement of their surface lenses is, in some case, precisely the same as in *Limulus*. The median eye of *Tremataspis*, like that of *Limulus*, probably consists of a complex group of three ocelli derived from the incomplete fusion of two pairs. They were, no doubt, true cerebral eyes, lying at the end of a tubular outgrowth of the brain. The distal end of this tube was probably bifurcate, the anterior vesicle containing one pair of ocelli lying beneath, or in, the median pit and the posterior vesicle lying in the paired median orbits. The anterior and posterior vesicles of *Limulus* and *Tremataspis* are represented in true vertebrates by either the vesicular ends of two separate outgrowths from the brain roof, one behind the other, or by two terminal vesicles, one in front of the other, arising from a common tubular outgrowth.

According to this view, the visual organs of vertebrates are derived from three pairs of segmental sense organs, originally situated near the margins of the cephalic lobes. The median eyes, which were the most anterior, were the first to be converted into cerebral eyes of the vertebrate type. This change took place in the arthropods, the various steps in the process being clearly seen in insects, crustaceans, and arachnids. The transfer of the lateral eyes to the cerebral vesicles and

their consequent inversion took place much later, probably in the intermediate type of animals to which the Tremataspidæ belong. It was during this period that the median eyes reached their highest development and the lateral eyes degenerated or, in some cases, disappeared completely from the surface. We have no means of knowing whether their temporary decline in functional importance was the cause, or the result, of their transformation into eyes of the cerebral type.

The *postorbital opening* probably contained the forerunner of the vertebrate olfactory organ. I have identified it with the frontal organ of *Limulus*, *Branchipus*, *Apus*, and others. This organ in the arthropods presents extraordinary variation in its position, but can always be identified by the peculiar histological structure of the terminal organ and its nerve, and by the origin of the nerve in the brain. In *Limulus*, no doubt, the organ was originally a visual organ serially homologous with the lateral and median eyes. In the adult it lies on the ventral side in front of the chelicerae. It gradually loses the histological characters of a visual organ and finally presents many points of resemblance to the olfactory organ of a vertebrate, especially in the structure and relations of its nerves. The hypostomeal eyes of trilobites are very probably homologous with the olfactory organs of *Limulus*. In *Branchipus* the same organ has moved from its original position on the ventral surface to a point on the dorsal surface almost as far back as the median ocellus. In *Apus* the two organs have moved still farther back and have united behind the median ocellus to form an unpaired organ in precisely the same location as the post-orbital opening of *Tremataspis*.

The *Oral Plates* have been worked out anew from the single fossil and its cast that was used by Rohon. My description differs from his in several very important respects.

According to my interpretation of this important fossil there are on each side nine large oral plates arranged in four rows. Some of the marginal plates are provided with one or more rounded incisions lying opposite corresponding incisions of the ventral and dorsal shields. The marginal plate of the fourth row is probably a compound plate. There is a row of four or

five small plates on each side, just behind the anterior margin of the dorsal shield.

A small triangular median plate lies in the anterior oral region. Its anterior margin seems to be articulated to the hinge-like process on the anterior median margin of the dorsal shield. The outer surface of the plate is smooth and provided with a low, keel-like ridge that gives it the appearance of the rostrum of an arthropod. Its apex lies considerably below the surrounding surface in a median depression that probably leads into a small circular oral cavity like that of an arachnid. There is no trace of a large transverse oral opening, like that described by Rohon, between the anterior plates and the anterior ventral margin of the dorsal shield.

The *anterior margin of the dorsal shield* is deflected sharply downward to form a low wall in front of the oral region. A small keel lies in the middle line on the posterior surface of the wall, with its rounded edge directed backwards. Two rounded toothlike projections of the rim, directed ventrally, lie on either side. The lateral margins of the dorsal shield are folded sharply toward the ventral median line and present three large rounded incisions that must be regarded as a forward extension of the series of six incisions of the ventral shield described by Schmidt and Rohon.

*The Appendages.* — The most anterior incision is the largest and is clearly the same as that so well seen on the margin of the dorsal shield in *Tolypaspis*, *Cyathaspis*, and *Pteraspis*, and which has been regarded as an opening for the lateral eye. Lindström's important discovery of an appendage in *Cyathaspis*, my own discovery of fragments of the appendages in *Tremataspis*, and a renewed examination of the pteraspids in the British Museum indicate that in these four genera the large anterior marginal incision served for the attachment of an oar-like appendage similar to that in *Pterichthys* and *Bothriolepis*. The remaining openings, which are unquestionably serially homologous with the first, must have served for the attachment of other appendages of a similar nature. They decreased in size from before backwards, and were possibly too delicate to be well preserved in a fossil condition.

*The Entapophyses and the Trabeculæ.*—It is doubtful whether the endolymphatic ducts of Rohon are actual perforations of the shell. In sections they are seen to be deep tubular infoldings, probably closed at the inner end. They appear to be comparable with those infoldings, or entapophyses, on the dorsal shield of *Limulus* which serve for the attachment of dorso-ventral muscles. This interpretation is strengthened by the fact that serial sections show the presence of another pair of bony ingrowths, just behind and in line with the so-called endolymphatic ducts. They are long deep plates that unquestionably serve for the attachment of muscles, since the frayed-out ossified tendons are still attached to their inner ends. These entapophyses are of great importance, as they indicate a similar arrangement of muscles and appendages to that seen in *Limulus*. They probably served for the attachment of dorso-ventral muscles, arising from the dorsal surface of the cartilaginous cranium and from the various pairs of cephalic appendages.

The presence of a similar set of muscles in *Pteraspis* and *Cyathaspis* is indicated by radiating impressions or lobes on the inner surface of the shell, similar to the radiating muscle markings on the dorsal wall of *Limulus*.

Transverse sections of the whole head show that the shell is specially thickened in the region of the crista occipitalis, and that the margin of the shield is considerably strengthened by a network of bony trabeculæ uniting the edges of the dorsal and ventral walls. The marginal trabeculæ are very similar to those I have described in *Limulus*. The marginal cells of *Eukeraspis* are probably produced by a special arrangement of these trabeculæ.

A loose network of bony trabeculæ is also developed round the median and lateral openings of the dorsal shield and along the incisions of the ventral wall where the appendages are attached. With the above exceptions, the inner surfaces of the dorsal and ventral shields are smooth.

The minute structure of the shell of *Tremataspis* and other members of the ostracoderms can be best explained, as we have pointed out elsewhere, on the assumption that it is a modification of a three-layered dermal skeleton similar to that of *Limulus*.



*The Resemblance between the Tremataspidae and the Arthropods.*—The following summary of the principal characteristics of the Tremataspidae shows how strongly they resemble the arthropods, and how surprisingly the resemblance has been strengthened at certain points by important discoveries in unexpected directions.

The Tremataspidae resemble the arthropods in (*a*) their general arthropod appearance, (*b*) in the minute structure of the shell, (*c*) in the structure and arrangement of the openings for the eyes and olfactory organs, (*d*) in the character and arrangement of the oral plates, (*e*) in the absence of vertebrate jaws and mouth and in the presence of a small centrally placed oral opening similar to that of an arachnid, (*f*) in the presence of numerous pairs of jointed appendages.

The presence of segmented appendages in Tremataspis and related forms is indicated by the following evidence: (1) the presence of a pair of oarlike jointed appendages, unlike those of any true vertebrate, in *Pterichthys*, *Bothriolepis*, *Cyathaspis*, *Pteraspis*, *Tolypaspis*, and *Tremataspis*; (2) the presence of a fringe of jointed and movable appendages (25–30 pairs) along the ventral margin of the trunk of *Cephalaspis*; (3) the presence of a pair of crushing mandibles like those of an arthropod in the head of *Cephalaspis*; (4) the presence in *Pterichthys*, *Bothriolepis*, and *Tremataspis* of oral plates that appear to be movable laterally, like the jaws of an arthropod; (5) the presence in *Tremataspis* of a series of eight other pairs of openings like the ones to which the large swimming appendages are attached; (6) the presence in *Tremataspis* of two pairs of entapophyses which, like those in *Limulus*, apparently serve for the attachment of muscles moving several pairs of appendages; (7) the presence in *Cyathaspis* and *Pteraspis* of from four to six radiating grooves on the inner surface of the dorsal shield, which, like similar markings in *Limulus*, indicate the points of attachment of dorso-ventral muscles moving several pairs of appendages.

The concurrent testimony, from so many different and independent sources, to the fundamental similarity between the Tremataspidae and the arthropods shows very clearly that the resemblance between them is due, neither to incidental



parallelism, nor to mimicry, but to genetic relationship and community of origin. It could not have been a remote relationship, signifying merely a common origin of both types from some annelid ancestor, because the resemblance consists in the common possession of highly specialized structures characteristic of the fully established arthropod and vertebrate types.

The genetic relationship, therefore, between the Tremataspidæ and the arthropods can mean nothing less than the derivation, through changes in structure and function, of one type from the other.

But we must not too hastily conclude that the Tremataspidæ are true arthropods, and by transferring them from one group to the other avoid the real problem at issue. We cannot so easily ignore the profound significance their structure has for the origin of vertebrates. Their vertebrate affinities are too obvious to be denied.

It is quite out of the question to separate the Tremataspidæ very far, either from the Cephalaspidæ on the one hand, as is conclusively shown by the similarity in the structure of their orbits, or from the Pteraspidæ and Pterichydæ on the other, as is shown by the appendages and the lateral-line markings, or from either, as is shown by the microscopic structure of the shell. The whole group must be kept together. But, as it is quite impossible to include in the arthropods a group of animals, nearly all of which have osseous dermal skeletons, and some of which have such characteristically vertebrate bodies and fins as the Cephalaspidæ and Pterichydæ, or to include in the vertebrates animals having many pairs of jointed appendages, it becomes necessary to create for them a new class, one that shall occupy a position between the true vertebrates and arthropods, and unite these two great groups into one compact phylum.

I propose for this new class the name *Peltacephalata*, and include in it forms like *Pterichthys*, *Cephalaspis*, *Pteraspis*, *Tremataspis*, and related genera. The class may be provisionally characterized as follows:

The *Peltacephalata* were arthropod-like animals, moving about through the soft mud on the bottom of shallow waters,

in the typical arthropod position. In many cases most of the body was probably concealed, leaving only the prominent median eyes exposed. The presence of paired oarlike appendages indicates the power of free swimming, but the more or less rigid and clumsy appendages and heavily armored body could have produced little more than brief, spasmodic excursions, like those of adult Limuli and eurypterids, or jerky, intermittent flights through the water, like those of a copepod. And, just as in these examples the shape of the body and the position of the appendages in reference to the center of gravity compel the free-swimming individual to reverse the usual position of dorsal and ventral surfaces, so in the Peltacephalata the prevalence of the same conditions must have forced them, after leaving the bottom, to turn over and swim with the neural side uppermost, in the true vertebrate position. The swimming movements were probably aided in some cases by numerous small appendages on the head and trunk. Fishlike caudal fins and tail were used in swimming and in reversing the position of the dorsal and ventral surfaces.

It was not till this new method of locomotion had completely replaced the old that the eyes left the hæmal surface (their position in most adult arthropods) and returned to the neural surface of the body (their position in embryo arthropods and their permanent position in vertebrates).

The *exoskeleton* was a true dermal armor of ectodermic origin, intermediate between the type presented by Limulus and that of the more modern vertebrates. It consisted of three principal layers, the middle one containing large, more or less regular spaces or cancellæ. The matrix was strongly laminated and penetrated by numerous dentine-like tubules, or pore canals, and contained either unipolar or multipolar osseous lacunæ. The trunk was covered with rhomboidal scales or with segmentally arranged ringlike plates. The presence of a system of superficial sense organs is indicated by numerous pitlike markings arranged in linear series.

A flattened cartilaginous cranium was present, but notochord and vertebral arches were absent or rudimentary. Median and lateral eyes were enclosed in bony orbits, sometimes protected

by hard convex coverings continuous with the outer layers of the shell. The median eye was large, complex, and important functionally. It consisted of two pairs of ocelli, one pair completely united in the median line and the other nearly so. The lateral eyes were reduced in size and in functional importance. The nasal pit was unpaired and, in some cases, situated behind the median eye. The mouth was small, circular, and situated near the center of a group of oral plates. No upper and lower jaws were present.

The head of the Peltacephalata may be regarded as a modification of the cephalothorax of an arthropod ancestor, consisting of three principal groups of segments, namely: the præesophageal, including all the parts derived from the cephalic lobes; the true thoracic segments; and the highly modified vagus segments, formed by the forward migration and their complete union with the thorax of from two to four abdominal segments. The brain, like that of vertebrates, probably consisted of three groups of neuromeres derived from these three sources.

The Peltacephalata have their nearest relatives among the known invertebrates in the Trilobita and Merostomata, having retained to a considerable extent the general shape of the body, the structure of the head, and the mode of life characteristic of these arthropods.

Sufficient data are as yet unavailable for a permanent arrangement of the Peltacephalata into orders and families, but some modifications of the old arrangement may be made to advantage. The old subdivisions into Osteostraci and Heterostraci, proposed by Lankester, should be abandoned, as they do not mark natural divisions. The discovery of heavily armored oarlike appendages in *Cyathaspis* and *Tremataspis*, and their probable presence in *Pteraspis* and *Tolypaspis*, unite these genera more closely with one another and with the *Pterichyde* than ever before. It is therefore inadvisable to isolate the pteraspidian section merely on the absence of multipolar bone cells, unless the *Pterichthyde* are united with the remaining families under the heading Osteostraci. But such an arrangement would not sufficiently emphasize the resemblance between

the oarlike appendages of Cyathaspis, Tremataspis, and Pterichthys, and the difference between these appendages and those of Cephalaspis.

Moreover, the Pteraspidae approach the Pterichydæ more closely than do the Tremataspidae in the division of the cephalic buckler into separate plates, and in its separation into a true cephalic or rostral portion bearing the median eyes, and a thoracic one to which the oarlike appendages are attached. On the other hand, Tolypaspis, which must be placed close to Pteraspis and Cyathaspis on account of the minute structure of the shield, shows no trace of a subdivision of its dorsal shield into separate plates.

It seems to me, therefore, that we must recognize four subdivisions of the Peltacephalata of about equal value, *vis.*, the Pteraspidae, Tremataspidae, Pterichydæ, and Cephalaspidae. The Cephalaspidae occupy a somewhat isolated position on account of the very peculiar shape of the head and the position and character of the appendages, although on the other hand, as shown by the connecting form Thyestes, a close relationship between Cephalaspis and Tremataspis is indicated by the resemblance between their median, lateral, and postorbital openings.

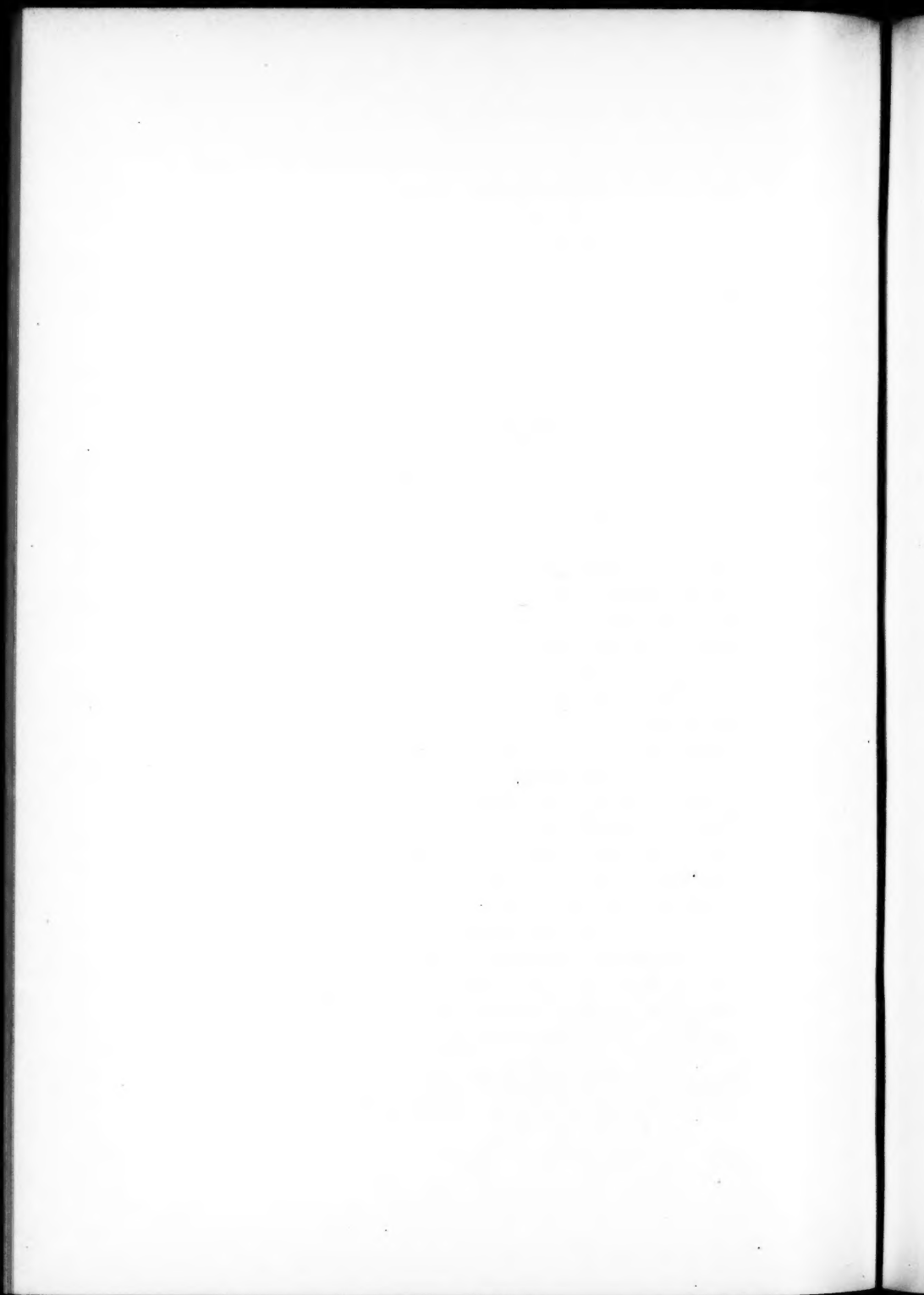
The Pterichydæ and Tremataspidae are bound together more closely than before, owing to their possession of oarlike appendages, large centrally placed orbits, and to the arrangement of the so-called lateral-line organs and oral plates.

*The Syncephalata.*—For the great phylum of the animal kingdom formed by the union of the vertebrates and arthropods I propose the name Syncephalata. The delimitation of the Syncephalata can be only roughly determined, especially at the lower end of the phylum. The main stalk consists of the Arachnida (including the Trilobita, Merostomata), the Peltacephalata, and the Vertebrata. The point of divergence from the main stalk of such groups as the Insecta, Crustacea, and the simplified and aberrant forms, like the Ternicata, Amphioxus, Balanoglossus, and others, are of minor importance and do not concern us here.

The justification of the term Syncephalata lies in the fact that in this vast series of segmented animals the concentration

and specialization of the anterior body segments into a head region is definitely begun and completed. It is only when this group is viewed as a whole that we see these momentous structural advances in their true perspective, and can follow the endlessly varied theme that leads steadily and consistently onward toward the completion of the most complex organic structure that has ever been produced, the vertebrate head.

DARTMOUTH COLLEGE,  
January, 1902.



VARIATION IN THE POSITION OF THE  
ADDUCTOR MUSCLES OF ANA-  
DONTA GRANDIS SAY.

ELLIOT R. DOWNING.

THROUGH the kindness of Mr. Frank C. Baker, curator of the Chicago Academy of Science, I have had the privilege of examining and measuring a number of exceptionally perfect shells of *Anadonta grandis* Say. These shells were taken in August, 1897, from "South Pond," Lincoln Park, Chicago, where they were closely associated as a colony. As the pond was thoroughly cleaned four years previously, the age of the oldest shells is definitely known. Not only do the annual limits of growth show, but internally the muscle scars and the paths of migration are very distinct (see figures).

During part of the year shell growth occurs rapidly and muscle migration is also rapid; again, growth nearly ceases, and the narrow dark band is deposited. During this slow growth the muscle is about stationary, and then the very distinct scar is formed.

The questions which I wished to settle were:

1. Does the muscle in its migration move at a rate proportional to shell growth, so that the muscle retains a fixed relation to the shell's proportions?

2. If not, how does it vary?

I chose for this study the ratio,

$$\frac{\text{distance from the umbo to the muscle}}{\text{distance from the umbo to the shell margin}}$$

In all the shells the separation of the anterior adductor from the anterior retractor is marked by a very distinct ridge, making a fine line which lies in the path of migration. The distance measured along this line on the curve of the shell, from the umbo

to the point where the outer boundary of the anterior adductor scar cuts the line, made the first term of the ratio (see  $x_1$ ,  $x_2$ , etc., Figs. 1 and 3). The second term was the distance from the umbo along this line produced to its intersection with the shell

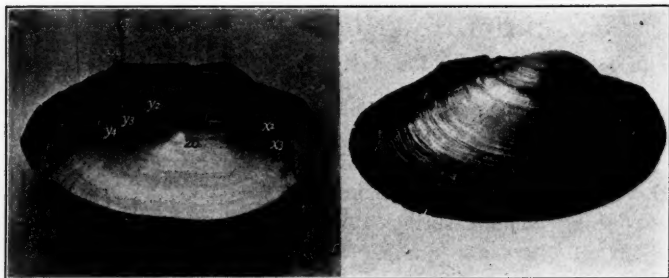


FIG. 1.

FIG. 2.

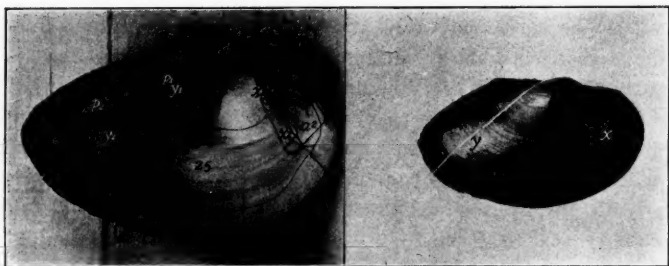


FIG. 3.

FIG. 4.

FIG. 1. — Interior of a four-year-old shell, impressions emphasized by ink lines.

FIG. 2. — Exterior of a four-year-old shell.

FIG. 3. — Interior of a two-year-old shell.

FIG. 4. — Exterior of a two-year-old shell.

$a_1$ ,  $a_2$ , anterior adductor scars;  $p_1$ ,  $p_2$ , posterior adductor scars;  $x_1$ ,  $x_2$ ,  $x_3$ , etc., points on ridge between anterior adductor and anterior retractor, fixed by its intersection with the adductor's outer margin;  $y_1$ ,  $y_2$ , etc., points on ridge at anterior limit of posterior muscle impression at which adductor margin is tangent to the ridge.

margin. A similar ridge is formed at the anterior margin of the posterior adductor. The first term of the ratio for the posterior adductor is the distance from the umbo to the point where this line is tangent to the adductor scar ( $y_1$ ,  $y_2$ , etc., Figs. 1 and 3). The second term is the distance measured



along this line produced, from the umbo to its point of intersection with the shell margin. The proportions then are:

$$\frac{\text{umbo to anterior adductor}}{\text{umbo to anterior margin}}, \text{ and } \frac{\text{umbo to posterior adductor}}{\text{umbo to posterior margin}}$$

The umbo in this species comes to a sharp point, which was in no case eroded. It afforded a definite point from which to measure. The measurements were made along the outer surface of the shell. The shells were thin and quite transparent, so that lines and points marked on the inside were readily traced by a soft pencil on the outside by holding the shell to a strong light (Fig. 4). Most of the shells were four years old, a few three, and some two. (The exteriors of two- and four-year-old shells are given in the figures.) Measurements were made and the ratios calculated for two hundred and seventy anterior adductor scars, and for the same number of posterior adductor scars.

In order to plot a curve for these ratios, the following classes were taken for the anterior adductor:

CLASSES.	FREQUENCIES.
.585 - .604	1
.605 - .624	8
.625 - .644	27
.645 - .664	38
.665 - .684	90
.685 - .704	64
.705 - .724	27
.725 - .744	13
.745 - .764	2
	<hr/> 270

The classes for the ratios of the posterior adductor are:

CLASSES.	FREQUENCIES.
.575 - .594	1
.595 - .614	8
.615 - .634	25
.635 - .654	71
.655 - .674	96
.675 - .694	45
.695 - .714	19
.715 - .734	4
.735 - .754	1
	<hr/> 270

Different limits for the classes were selected in the seriation so as to give in each case the most nearly normal distribution of frequencies.

Laying off the frequency polygon by the method of rectangles gives Figs. 5 and 6, both curves of Type 4. The essential data for these curves are :

	ANTERIOR.	POSTERIOR.
A	.6783	.6613
$v_1$	.0033	-.0037
$u_3$	-.00000138	-.00000297
$B_1$	.00005	.041
$B_2$	74.47	1388.8
F	-142.94	-2771.47
$\alpha$ (skewness)	-.00028	-.022
$\sigma$ (index of variability)		
	.0287 $\pm$ .00083	.0254 $\pm$ .00073

#### *Discussion of results.*

1. *The distance of the adductor muscle from the umbo, measured along the line of migration, varies considerably in its relation to the distance to the shell margin, measured along the same line produced. The extreme ratios are .591 and .754. The measurements in the latter case are  $\frac{49 \text{ mm.}}{65 \text{ mm.}}$ . To produce the former proportion we should have to have 37.3 mm. instead of 49 mm., —a change of 11.7 mm., or nearly  $\frac{1}{4}$  of the total measurements.*

2. *While the range of variation then is comparatively large, yet the frequencies are well concentrated at or near the mode. In 93 per cent of the cases the position of the muscle would not vary 3 mm., in either direction from the mean position.*

3. *Roughly speaking, we may say that the muscle is situated two-thirds of the way from the umbo to the margin. Accurately, the mean ratios are .6757 for the anterior muscle and .6608 for the posterior.*

4. *It was thought at the outset of the investigation that the results might indicate a difference in the rate of migration of the adductor muscles, one approaching the shell margin at a more rapid rate than the other. The negative skewness of both*

curves, however, would indicate a tendency toward smaller ratios; that is, a decrease in the relative distances from the umbo to the muscle impression. This may mean that the muscles migrate constantly less rapidly than the margins grow. Since the skewness is least in the anterior adductor curve, the anterior adductor tends to move toward the margin at a more rapid

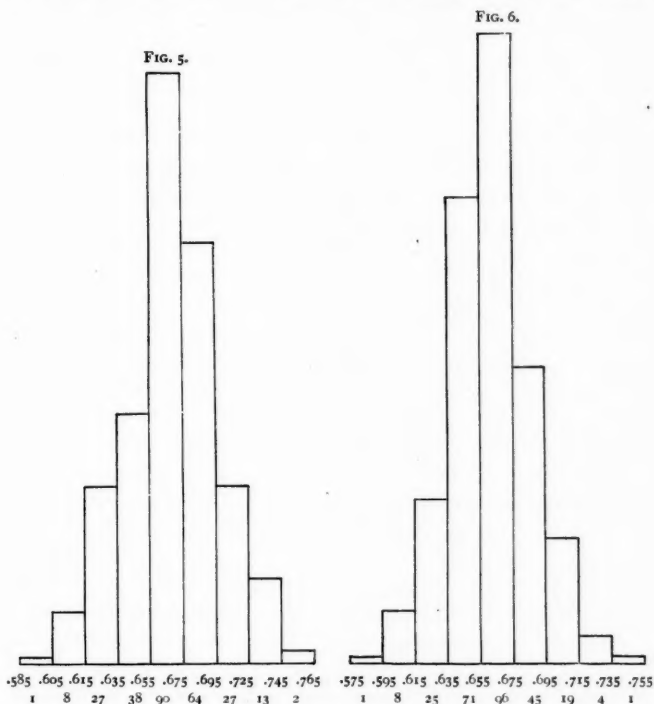


FIG. 5. — Frequency polygons for anterior adductor ratios.

FIG. 6. — Frequency polygons for posterior adductor ratios.

rate than the posterior, although there is a tendency in both to lag behind the rate of growth of the shell margin. The greater variability of the anterior muscle position would indicate that it is the muscle most concerned in the evolutionary process. However, variability and skewness are both so slight that the above conclusions must be tentative until

further evidence can be adduced. We seem to have in this form a species that is stable, rather than one that is in process of rapid evolution.

I am indebted to Dr. C. B. Davenport for valuable suggestions and assistance in carrying on this study.

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## NOTES AND LITERATURE.

### ZOÖLOGY.

**Temperature of Insects.** — Professor Bachmetjew's<sup>1</sup> paper is one of those rare publications which is full of interest not only to the specialist in entomology but to biologists in general. The Russian author, with the equipment of the trained physicist, approaches a subject that has often been studied before, and after treating it in an exhaustive manner reaches new and important results, which would carry conviction in their very simplicity, even if they were not substantiated step by step by detailed tables of observations. The work of all previous investigators in determining the vital temperature of insects is briefly and critically reviewed as a preface to each of the main sections of the work.

In order to determine the temperatures, the insect was spitted through the thorax on a thermoelectric needle consisting of fused manganin and steel wires connected with a galvanometer. A detailed account of the somewhat complicated apparatus and the method of using it are given in an appendix (pp. 138-142). A number of different insects, mostly larger moths, butterflies, and beetles, both pupal and imaginal, were used in the experiments.

The first part of the work is devoted to a consideration of the body temperature of insects. In his earlier experiments, Bachmetjew came to the conclusion that the temperature of the insect body varies within very considerable limits, apparently without any serious consequences to the life of the animal. He found, moreover, that in resting insects the temperature is the same or very nearly the same as that of the surrounding air. Subsequent experiments, however, led him to conclude that this is true only under ordinary conditions of moisture, temperature, etc., since these factors, when abnormal, have a very pronounced effect on the body temperature. Under normal conditions, when the temperature of the atmosphere is raised, the temperature of the insect, though rising, lags at first more and more behind

<sup>1</sup> Bachmetjew, P. Temperaturverhältnisse bei Insekten. Experimentelle entomologische Studien vom physikalisch-chemischen Standpunkt aus. Bd. i, pp. 4-160. Leipzig, Wilhelm Engelmann, 1901.

that of the atmosphere, and only begins to approach atmospheric temperature just before partial heat paralysis of the wing muscles sets in. After death the temperature of the insect and the air are the same. But when the air is very damp the body temperature of the insect is higher than that of the air. This is explained as due to evaporation of the body fluids and to respiration, the former having a tendency to diminish, the latter to raise, the temperature of the insect. Bachmetjew predicts that the study of the dependence of the body temperature on that of the air, under different conditions of moisture, will ultimately enable us to determine the metabolism of these animals, and hence their vitality at different temperatures.

The influence of the activity of the insect on its body temperature, long since noted by Newport (1837) and others, is exhaustively studied by Bachmetjew. While a moth is moving its wings its body temperature keeps rising, but falls suddenly with the cessation of this movement. The insect was studied under three conditions: first, at the ordinary temperature of the room; second, at a higher temperature in the thermostat; third, at a lower temperature in a cold-air bath. Experiments conducted at room temperature show that the moth (*Sphingid*) is incapable of raising its own temperature higher than  $38.5^{\circ}\text{C}$ . by means of muscular movement. Fluttering of the wings does not produce as high a temperature as "humming." At about  $38^{\circ}\text{C}$ . the insect often suddenly changed from humming to fluttering, or rested completely. Bachmetjew interprets this change as due to partial heat paralysis of the muscles. It is a transitory phenomenon, which disappears with the sinking of the temperature during rest to that of the surrounding atmosphere. The temperature at which the wing muscles are paralyzed (in *Deilephila euphorbiae*) increases with an increase of the temperature (at ordinary moisture) and reaches  $45.5^{\circ}\text{C}$ ., after which the moth loses the power of humming. Complete, *i.e.*, no longer transitory, heat paralysis of these muscles supervenes at a body temperature of  $49.7^{\circ}\text{C}$ . In somewhat moister air this result does not set in till  $53^{\circ}\text{C}$ . is reached. In a single experiment on *Deilephila* at low atmospheric temperature the muscle paralysis also appeared, but at a lower temperature. At a body temperature of  $-0.5^{\circ}\text{C}$ . all movements ceased, fluttering began at  $12^{\circ}\text{C}$ ., and humming not till  $20^{\circ}\text{C}$ . had been reached. It would seem, therefore, that the temperature of partial paralysis of the wing muscles is directly proportional to the body temperature of the insect, as is also the case for higher temperatures. According to Bachmetjew, these effects of partial paralysis play a great rôle in the production

of color aberrations in butterflies. He also suggests that further study of these effects may explain why so many moths are nocturnal, while the butterflies are diurnal. Some experiments on the influence of respiration showed that *Deilephila* at 29.4° C. atmospheric temperature could raise its body temperature through at least 3° C. by means of breathing alone.

The second and more important portion of Bachmetjew's paper deals with the vital extremes of temperature. It is divided into two sections, one dealing with the maximum, the other with the minimum temperature. The vital maximum is the highest temperature at which an insect is able to live. Experiments on *Saturnia pyri* showed that the insect becomes very restless at a temperature of about 39° C. and dies when the body reaches a temperature of 46° C. This is also very near the lethal temperature for plants (Sachs and Schultze). This lethal temperature, however, depends on a number of factors. In general, it may be said that if the insect at high temperature first, has not been exhausted, *i.e.*, has been artificially fed; second, is not desiccated, *i.e.*, is in a sufficiently moist atmosphere; and third, presents the same conductivity to heat and the same body size for a given species, — its life will depend only on the coagulation or non-coagulation of its body fluids. Hence, the vital maximum is only another expression for the coagulation point of the body fluids. And if one knew the amount of water in the insect's albumins, especially of those albumins essential to life, the question of the vital maximum would resolve itself merely into a determination of the amount of water.

Bachmetjew's study of the vital minimum, *i.e.*, the lowest temperature at which an insect can live, brought out some startling results. He found from experiments on a great number of insects that different species died at very different temperatures. But his most interesting results refer to the critical point, which is the temperature to which the fluids of the insect may be undercooled before they begin to congeal and then suddenly rise in temperature till the normal congealing point is reached. Bachmetjew points out the resemblance of this phenomenon to the well-known undercooling of water, which can be cooled to -25° C. without freezing, but at once rises to 0° C. to freeze. Bachmetjew discovered the undercooling of the body fluids of insects by accident in an experiment on *Saturnia pyri* ♀. The insect was cooled to -9.4° C., whereupon within a minute's time the temperature bounded up to -1.4° C., the normal congealing point of the body fluids, and then remained constant for

eleven minutes. In this case the critical point is  $-9.4^{\circ}$  C., and  $-1.4^{\circ}$  C. is the normal congealing point. This insect revived within an hour after the experiment, and laid eggs on the following day. From this Bachmetjew concludes that the mere congealing of the body fluids is not lethal. In a second experiment a moth of the same species showed a critical point of  $-11.6^{\circ}$  C. (4.25 P.M.), whereupon the temperature rose at once to  $-1.1^{\circ}$  C. The insect was kept in the cold, the temperature of its body again sinking to  $-15.6^{\circ}$ . At 6.15 P.M. it was removed to the temperature of the room, but could not be revived. It follows that the insect dies if its body is still further cooled after the rebound (the limits being not necessarily higher than  $-2.5^{\circ}$  C. nor lower than  $-15.6^{\circ}$  C.), or, as a general rule, it may be stated that the insect dies if its temperature be again reduced to about the point from which it rebounded. Further experimentation on this interesting subject led to the following general conclusions here briefly transcribed. The extreme degrees of undercooling of the fluids differ in different insects, and these extremes occur at nearly the same rate of cooling. The critical point, so far as its absolute minimum is concerned, is greater in pupæ than in imaginal moths and butterflies, whereas the maximum differs in pupæ and imagines. Owing to lack of material, the behavior of the larvæ could not be determined. With respect to sex, the degree of undercooling of the fluids in normal specimens is lower in the males than in the females. This is also the case after brief fasting; after protracted fasting, however, the degree of undercooling is lower in the males, but finally becomes the same in both sexes. On the other hand, the normal congealing point of the fluids is lower in the females than in the males. After fasting, it is the same in both sexes; but after protracted fasting, the relation is again reversed. Further investigation of this question showed that the insect juices have a lower critical point when the insect is fasting, but so far as its absolute magnitude is concerned, it diminishes on continued starvation. Repetition of undercooling gave the following results: On freezing a second time strong Lepidoptera exhibit a much greater degree of undercooling than on the first freezing; on being frozen a third time the fluids show almost no undercooling. This is also shown by weak Lepidoptera on the second cooling. Bachmetjew also studied the influence of the fluid coefficient on undercooling. If  $M$  be taken as the total weight of the living insect, and  $P$  its weight after drying on a water bath for a long time at a temperature of  $115^{\circ}$  C.,  $M - P$



would represent the weight of the fluids which leave the body on evaporation at this temperature. The relation

$$\frac{M-P}{M} = q$$

is known as the fluid coefficient and signifies the percentage of fluids in a unit of weight of the living insect body. Experiment shows that the smaller the fluid coefficient the lower lies the normal congealing point of the fluids. The critical point is also influenced by the fluid coefficient, but this influence cannot be stated in general terms till the composition of the fluids has been further studied. Time also influences the critical point. If the temperature ( $t$ ) to which the insect is undercooled coincides at the same rate of cooling with the critical point ( $K_1$ ), the juices at once begin to congeal (*i.e.*, time = 0); but if  $t$  does not coincide with  $K_1$ , the congealing of the fluids is delayed in proportion to this difference ( $K_1 - t$ ).

Undoubtedly Bachmetjew's results are of a far-reaching character and will ultimately form the basis for important work along theoretical lines in physiology, and for practical applications of great moment (in economic entomology, *e.g.*!), for they throw light on the geographical and climatic distribution of organisms, the resistance of animals and plants to cold and heat, and the problems of anabiosis. That Bachmetjew himself is very sanguine concerning the results that may ultimately flow from his work is apparent when he says. "Es eröffnet sich somit ein ganz neues Gebiet für die Forscher, und wer weiss, ob die Zeit nicht nahe ist, wo man den märchenhaften hundertjährigen Schlaf auch bei Menschen künstlich hervorrufen könnte! Die Insekten wenigstens bieten die Möglichkeit dazu."

W. M. W.

**An Important Paper on Phoridae.**—Theodor Becker, of Liegnitz, Prussia, has recently published a work<sup>1</sup> of 100 pages, with five plates, on the family Phoridae, which deserves notice among zoölogists in general because it is one of the finest pieces of systematic work that has been published on the Diptera.

The family Phoridae includes only small species, generally from two to four millimeters in length, which do not offer to the observer with a hand lens a satisfactory series of specific characters. The genus *Phora* was early described and generally recognized from its

<sup>1</sup> *Abhandlungen der k. k. zool.-botan. Gesellschaft in Wien*, Bd. i, Heft 1, 1901.

peculiar venation; this led to the description of a large number of species by the earlier dipterists, among them Meigen, Macquart, Zetterstedt, Bohemann, Haliday, Rondani, and Egger, the types of which ultimately found lodgment in various public museums of Europe. Most, if not all, of these describers based their species chiefly on size and color, having but little comprehension of the real specific distinctions. When they came to identifying each other's descriptions, confusion was worse confounded, and down to the present time it has been impossible to get the family, which is mostly comprised in the single genus, into intelligible shape.

Mr. Becker secured for study the material contained in twelve public museums of Europe, including all the types now in existence of the earlier descriptions, with a few exceptions. He not only made a thorough study of all these collections, but he has published a full report in this work on the named species and types in each, thus putting the old species in a perfectly clear light and preventing future disputes over alleged types and misnamed species in these collections.

In addition to this material and that in his own collection, Mr. Becker was able to study the collections of some eight dipterists of the present generation, so that his work may fairly be termed exhaustive.

Sixty-five European species of the genus *Phora* are described, of which twenty-two are new. The remainder of the family, as represented in Europe, consists of *Trineura*, three species; *Conicera*, two species; *Gymnophora* and *Metopina*, one each.

The arrangement of the paper is admirable, and includes the following sections: table of genera of the world; structure and characters of the genus *Phora*; analytical table of species; description of species; enumeration of the named species in each of the type collections examined, with the proper status of each specimen; a brief division on biology; other European genera and species; extra-European genera, with their species; index of European species, including synonyms; list of accepted European species; list of extra-European described species in the family, with references; explanation of plates, and table of contents. This will give an idea of the completeness of the work.

The characters used are largely those of the bristles, the "chaetotaxy" of recent writers; without the use of these bristles it would be impossible to write an intelligible description of many of the species. There is no family of flies in which it is more essential.

One might wish to see a more extended notice of the biology of the Phoridae, but as long as we have not yet nearly reached the point where we can extend our classification to the larval stages, it is not improper to allow the natural history of the species to form a separate subject.

This paper will be of great advantage to American workers, as it will enable them to ascertain how far our species are identical with the European, Becker's descriptions being so exact that it will be possible to determine without comparison of specimens, I should judge.

To take up a family that is in a state of chaos and transform it into order and beauty by a single publication is a great achievement, and one not accomplished without long and arduous study. Mr. Becker has produced a monumental work, easily the greatest he has yet attempted, and one which may well be taken as a model by younger entomologists.

J. M. A.

**Habits of Insects.** — An English rendering of the first volume of Fabre's delightful *Souvenirs entomologiques. Études sur l'instinct et les mœurs des insectes*, though with an exceptionable title and an overburdened title-page,<sup>1</sup> is to be heartily welcomed. It makes accessible to a larger circle some of the early work of a keen inquirer into the faculties of insects. Well and favorably known since 1879, Fabre's observations have instigated similar and successful work elsewhere, and it is only from the philosophical side, Fabre being a rigid opponent to any form of evolution, that his writings are open to hostile criticism.

The volume under notice begins with an account of the habits and life history of *Scarabæus sacer*, and is devoted almost wholly to the higher Hymenoptera, though incidental observations concerning other insects are given.

With due allowance for the many difficulties, the translation is fairly well done. Editorially the volume cannot be considered as altogether satisfactory; the supervision of an entomologist should have precluded the translation of *grillon* indifferently as "cicada," "cricket," or "grasshopper," the almost universal use of "feet"

<sup>1</sup> Fabre, J. H. *Insect Life. Souvenirs of a Naturalist.* Translated from the French by the author of *Mademoiselle Mori*. With a preface by David Sharp. Edited by F. Merrifield. With illustrations by M. Prendergast Parker. London, Macmillan & Co.; New York, The Macmillan Company, 1901. xii + 320 pp., 16 pls.

(*pattes*) for "legs," and the frequent confusion between genus and family.

Footnotes recording similar work or opposite conclusions would have been valuable, and the lack of an index is especially regrettable.

S. H.

#### BOTANY.

**The Rhodomelaceæ.**—Originally planned as one of the series of monographs of the marine organisms of the bay of Naples, the author<sup>1</sup> of this work has extended its scope until now it covers the entire family of the Rhodomelaceæ, as represented in all waters. Of its large quarto pages 109 are given to the general part, covering the anatomical development of the stem, the morphology of the vegetative organs, and the reproductive organs; 588 pages are given to the special part, with detailed studies of all the species found in the Neapolitan region, and of all other species authentic specimens of which were accessible to the author; 248 species are elaborately treated in this part. The third part, "Systematic Results," 34 pages, includes notes on phylogeny, on the relation of the Rhodomelaceæ to other families, and a synoptical view, practically a key to the genera of the Rhodomelaceæ, giving under each genus the names, with descriptions, of the species described in the second part, and of such other species as the author had reason to consider sufficiently studied to leave no doubt of their position under his arrangement. The large genera *Laurencia* and *Polysiphonia* are excepted from this full treatment, only a portion of the species being mentioned, about which the many other species can be grouped; even with this reduction, 320 species are given in this third part.

A monograph of this character, from the hands of the one person competent for the task, is an important event, and the care and thoroughness with which it is done are remarkable. The author undertook the task in 1878, and some of the plates were printed in 1885; after all, this long stretch of time seems none too much for the enormous amount of work involved. What the future may

<sup>1</sup> Falkenberg, R. *Flora und Fauna des Golfes von Neapel*. 26. Monographie. Die Rhodomelaceen. Herausgegeben von der Zoologischen Station zu Neapel. Berlin, 1901. xvi + 754 pp., 24 pls.

bring, no one can tell, but it is difficult to imagine anything that will affect, except in details, so logical and well-grounded a classification as this.

In 1889 Schmitz published his *Systematische Uebersicht der bisher bekannten Gattungen der Florideen*, and in 1897 "The Rhodophyceæ," in Engler and Prantl, *Die Natürlichen Pflanzenfamilien*, was from the manuscript left by Schmitz at his death; in both of these the Rhodomelaceæ were based on Falkenberg's studies, but in both changes were made, with Falkenberg's consent, from his original plan, to conform with Schmitz's general system. In the present work no such change was needed.

The nomenclature of the present work, as compared with J. G. Agardh's, the former standard, shows considerable change. Few new species have been described, and consolidation of existing species has, apparently, at least equaled their division; but the larger genera have been split up, so that the number of new binomials is quite considerable. The increased number of genera seems the result of a logical employment of certain definite characters throughout the family, — monopodial or sympodial growth, radial or dorsiventral character of the frond, endogenous or exogenous character of the regularly distributed branches, presence or absence of "leaves" in addition to the branches, number of pericentral cells, their persistence unchanged or ultimate division, etc. The sexual organs are practically uniform throughout the family, and where the arrangement of the tetraspores appears to offer distinctive characters, it is probably due to the structure of the branches in which they are formed. In conformity with the general algological practice, no attempt has been made to substitute dead and forgotten generic names for long-established ones of later date, but in some cases the older names are given as synonyms; this last may be quite a convenience for persons wishing to attach their names to new binomials, though not familiar with the plants in question.

Many American forms are studied and figured, representatives occurring of the new genera Brongniartella, Bryocladia, Dasyopsis, Falkenbergia, Herposiphonia, Heterosiphonia, Lophocladia, Lophosiphonia, Ophidocladus, Pterosiphonia and Wrightiella; genera, that is, that may be considered as new, for although most of them appear in Schmitz's papers previously mentioned, they now for the first time are given with full characters and list of species included.

*Rhodomela floccosa* of our northwest coast is transferred to Odonotalia, a very satisfactory place for the luxuriant, pinnately branched

plant of the northern Pacific; but there are other forms passing under this name of quite different habit, for which a place must be found somewhere else. *Polysiphonia bipinnata* Post. and Rupr. is referred to *Pterosiphonia*, but with exclusion of *Polysiphonia californica* Harv., hitherto generally regarded as a synonym. This transfer being based on original material is undoubtedly decisive, but, as in the case of *Rhodomela floccosa*, we are left with a long series of forms, some of which will not go into *Pterosiphonia*. It may be that they can be included in *Polysiphonia californica*, but more study is needed. *Chondria baileyana* Harv. and *C. sedifolia* Harv. are restored to specific rank, but in actual collecting it is not easy to draw the line between the former and what is called *C. tenuissima* on the northeast coast, and between the latter and *C. dasyphylla*.

In regard to the Baltic forms of *Polysiphonia violacea* (Roth) Grev., which Reinke considered identical with *P. harveyi* Bailey and *P. olneyi* Harv. of the American coast, denying autonymy to these two species, the author considers Reinke's identification an error, Harvey's types being amply distinct from the Baltic forms. This is a relief to American algologists, who were about ready, if *P. violacea* and *P. harveyi* were united, to accept one name for all four-tubed *Polysiphonias* whatever. The union under *Rhodomela subfusca* (Woodw.) Ag. of such various forms as *R. lycopodioides* (L.) Ag., *R. virgata* Kjellm., and *R. rochei* Harv. is possible only by giving an extreme range in habit and mode of fruiting. It still seems as if *R. subfusca*, taken in so broad a sense, must be an aggregate, to be divided sooner or later.

A work as thoroughgoing as the present, and starting from the foundations, must continually reach conclusions differing from those of previous writers, and the author states these divergences and contradictions with great frankness; not ill-naturedly, but sometimes apparently with a little impatience with errors which could have been avoided by a little more careful observation. Practically every one who has written on or referred to the *Rhodomelaceæ* comes in for correction sooner or later, most of all the late Professor Agardh, both as the most conspicuous writer and because in spite of, perhaps in consequence of, his remarkable intuitional perception of systematic relations among the algæ, he was never a careful and punctilious student of the development of their structure, and it is upon the development, rather than on the mature structure, that the classification of the present work is based. As compared with the elaborate synonymy of Bornet and Flahault's

monograph of the heterocysted Nostochaceæ, the synonymy here is quite meager; those who are interested in the *ganzen Ballast veralteter Namen aus jener Zeit* are referred to Agardh's, Kutzing's, and Harvey's works. References to standard plates are abundant, but there are practically no references to published exsiccatae, which is often unfortunate; a plate can tell only what the artist saw, or even only what he chose to represent; the plant itself, if in proper condition, is ready to answer questions that never occurred to the artist or the author. The plates in the present work give an instance of this: when a figure is intended to show the position of certain cells, it shows that with the utmost distinctness, but usually nothing more; no indications of thickness of cell walls, character of chromatophores, etc.; where some other character is under consideration, that is given the prominence, to the exclusion or subordination of all others. The plates, however, tell admirably what they undertake to tell; if we were told also where we could find the plant itself, nothing more could be asked. But some remarks by the author as to specimens which belong to several distinct species and appear as autograph authentic specimens of a single species may account for a reluctance to give exsiccatae numbers.

The work is written in a clear and comprehensible style, and now and then contains a graphic expression, which, if not necessary for scientific value, certainly does not detract from it. It would seem that any student, with even a fair knowledge of German, could use the work readily. The ordinary American student, however, will be more likely to borrow the copy of some well-to-do friend than to own one, the price being 120 marks.

**Californian Nitophylla.**<sup>1</sup>—In the historical sketch with which this paper opens, the first reference to Californian Nitophylla is given as "W. H. Harvey, 1858, Pt. II, p. 104, Suppl., p. 128." This is misleading, as Part II of the *Nereis* was published in 1853; Part III, with the supplement, in 1858. Thus the history of Nitophyllum in California dates back five years earlier than given by the author. The latest reference is in 1898, when J. G. Agardh published Vol. III, Part III, of the *Epicrisis* (noticed in the *American Naturalist* for June, 1899), giving fourteen species for the west coast of America. Mr. Nott's careful study of living and dried material, from all parts of the coast, shows that six of these must be

<sup>1</sup> Nott, Charles Palmer. Nitophylla of California, Description and Distribution, *Proc. Cal. Acad. Sci.*, Ser. 3, Botany, vol. ii (1901). 62 pp., 9 pls.



considered merely forms of the other eight. A new species, *N. corallinarum*, is added, together with the New Zealand species, *N. harveyanum*, making the final list ten.

The genus has a world-wide distribution and includes many handsome species, with large, delicate, more or less veined membranes of various shades of red. The Californian species are not inferior to others in size and beauty, and the present paper gives a careful study of them, with ample description, full synonymy and references. The considerable variation occurring in some species is noted as accounting for the new species proposed by Agardh; unless one had a large series of forms of *N. ruprechtianum*, for instance, it would be perfectly natural to describe extreme forms as distinct species.

The plates illustrating this paper are by a photolithographic process, and, while showing fairly well the habit of the broader membraned species, are less satisfactory with the other species. Dependence in determining must be had on the text and the references to exsiccatae.

**Alaskan Algæ.**—This paper<sup>1</sup> gives quite an addition to our knowledge of the marine and fresh-water flora of our northwest coast, nearly half of the marine and more than half the fresh-water species being new to Alaska. The really northern flora of the west coast begins at Puget Sound, practically all the species from this point north being distinctively northern in character, though some of them extend south to central California. Of the red and brown algæ, 55 are circumpolar or found in the north Atlantic, 49 peculiar to the Pacific. In the table, p. 394, these 49 species are in a column headed "Peculiar to the Pacific Coast of North America." As this column includes such Asiatic species as *Cystophyllum lepidium* and *Odonthalia kamtschatica*, and such south Pacific species as *Macrocystis pyrifera*, the heading is very misleading. If it were intended to say that they were not found on any coast of North America except the Pacific, it would be true, but that is not the natural meaning of the words. Nine new species are described and figured by Mr. Saunders, *Streblonema pacificum*, *S. irregulare*, *S. minutissimum*, *Dermocarpa fucicola*, *Homæostrota lobatum*, *Myelophycus intestinalis*, *Coilodesme linearis*, *Mesogloia simplex*, and *Alaria fragilis*; also *Pleurophycus gardneri* Setchell and Saunders; a few less familiar forms already described are figured, a plate is given of a

<sup>1</sup> Saunders, De Alton. Papers from the Harriman Alaska Expedition. XXV. The Algæ. *Proc. Wash. Acad. Sci.*, vol. iii (Nov. 15, 1901), pp. 391-486, Pls. XLIII-LXII.



Liebmannia (?) but without specific name, and some 60 species of desmids are figured on Plates XLIII and XLIV.

*Nereocystis priapus* (Gmelin) Saunders takes the place of *N. Luetkeanus* Mert., universally accepted since its publication in 1829. While it is probable that Gmelin's plate of *Ulva priapus*, published in 1768, represents a fragment of a frond of this species, no one before Mr. Saunders has proposed the change, though Gmelin's name has often been mentioned as a possible synonym.

Some curious phrases occur: p. 426, *Alaria lanceolata* is said to be "easily recognized by the tufts of long cryptostomata"; p. 434, *Iridea membranacea* J. Ag., "To this species Dr. Farlow has very questionably referred," etc. The context shows that "questionably" is used in the sense of "doubtfully," and the word is used in apparently the same sense (p. 440) in regard to *Gloiosiphonia californica*. On p. 438 there are notes on the "perithecia" of two species of *Odonthalia*. There is a curious tendency to give specific names the feminine ending in all genera whose names end in *a*. In the table, p. 394, this is consistently carried out, — *Streblonema pacifica*, *Homastroma undulata*, etc. In the descriptive text, later, some are changed to neuter, others continue feminine. Possibly these are only instances of the misprints which abound in the names throughout the paper, due in part to scanty time allowed for correction of proof, and perhaps to volunteered corrections by some other than the author. See p. 414, *Cladophora arctica* for *C. arcta*.

The plates are clearly drawn and printed, the descriptions of new species are fairly complete, and, as a whole, the paper is a valuable addition to our knowledge of the plants of our northwestern possessions.

**Agardh's Algæ.**<sup>1</sup> — In the notice of Part III of this work, in the *American Naturalist* for June, 1899, attention was called to the long time, the greater part of the nineteenth century, of Agardh's work in this field, and the hope was expressed that the paper under consideration might not be the last. One more part has been issued, but only half of the proof had been read by the author at the time of his death. In this part there is a rearrangement of the genus *Gracilaria*, notes on some other genera, and an article, "On the Principles of Classification to be adopted for the Floridæ." This he considered as of great importance, as a final statement of his

<sup>1</sup>*Species, Genera et Ordines Algarum*. Auctore Jacobo Georgio Agardh. Vol. iii, pars iv (Lund, 1901), pp. 149.

views, and something of a protest against the Schmitzian principles. At eighty years of age one does not readily give up the principles upon which one's life work has been based, but every system, when it has done its work, must give place to something else, at least until our knowledge has advanced far beyond its present state.

But the Agardhian system has been very useful in its day, and with the death of its author we lose one of the most conspicuous figures in the botanical field. Born in 1813, the son of C. A. Agardh, the foremost algologist of his time, his publications range from 1836 to 1901, the first part of the work whose last part we have just noticed appearing in 1848. His main characteristics were his quick grasp of a situation, however complicated; his unerring instinct for really important characters; his prompt recognition of true affinities. With this type of mind, the toilsome, plodding investigation required by modern conditions was not to be expected; but it was the type of mind needed to bring order out of the chaos of conflicting schemes prevailing at the time, and to arrange the great numbers of new forms coming to light in all parts of the world.

In person, as in mind, Agardh might be classed with the Norse giants. Tall, well formed, athletic, dignified, serenely confident of his position, he was a benevolent, gracious potentate of botany. Very liberal in the distribution of specimens, he yet, like all royal personages, held some in favor and some in disfavor, and more than one private student in America has received from him a finer set of his algæ than can be found in Berlin, or some other great botanical centers. The name *Agardhia* having been used in honor of his father, *Agardhiella*, a genus of red algæ with one handsome species on our Atlantic coast and one on the Pacific coast commemorates him, while many species bear his name. The red algæ were his special field, and in spite of all of the modern advances it will be long before his works cease to be the place to which one will naturally first turn when studying these plants.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS,  
RETIREMENTS, AND DEATHS.

EDUCATIONAL GIFTS.

- Allegheny College, \$200,000, from various donors.
- Amherst College, \$15,000, from an anonymous donor; \$1000, from Warren F. Draper.
- Athol (Mass.) Public Library, \$15,000, from Andrew Carnegie.
- Atlantic, Iowa, \$12,500, from Andrew Carnegie, for a public library.
- Baraboo, Wis., \$12,000, from Andrew Carnegie, for a public library.
- Barnard College, \$250,000, from John D. Rockefeller; \$250,000, from other sources.
- Beatrice, Neb., \$20,000, from Andrew Carnegie, for a public library.
- Benton Harbor, Mich., \$15,000, from Andrew Carnegie, for a public library.
- Blue Island, Ill., \$15,000, from Andrew Carnegie, for a public library.
- Boston Public Library, \$100,000, from the estate of the late Nathan Haskell Dole.
- Bozeman, Mont., \$15,000, from Andrew Carnegie, for a public library.
- Brazil, Ind., \$20,000, from Andrew Carnegie, for a public library.
- Brown University, a conditional gift of \$75,000, from John D. Rockefeller; \$100,000 and the residuary estate (which may amount to \$500,000) by the will of Geo. L. Littlefield.
- Buchtel College, \$20,000, from several donors.
- Carroll College (Wis.), \$20,000, from Ralph Vorhees.
- Cedar Falls, Iowa, \$15,000, from Andrew Carnegie, for a public library.
- Charlotte, Mich., \$10,000, from Andrew Carnegie, for a public library.
- Chicago Heights, Ill., \$10,000, from Andrew Carnegie, for a public library.
- Clark University, \$100,000, by the will of Jacob Wheelock.
- Columbia University, \$3000, from Adolph Lewisohn; \$100,000, from an anonymous donor; \$50,000, by the will of Mrs. Lila Currier; \$11,000, from an anonymous donor.
- Cooper Union (N.Y.), \$300,000 each, from Andrew Carnegie and the descendants of Peter Cooper; an anonymous gift of \$250,000.
- Denison, Iowa, \$10,000, from Andrew Carnegie, for a public library.
- Denver Public Library, \$200,000, from Andrew Carnegie.
- Fulton, N.Y., \$15,000, from Andrew Carnegie, for a public library.
- Greensburg, Md., \$15,000, from Andrew Carnegie, for a public library.
- Hamilton College, \$50,000, from the alumni.
- Hampton, Iowa, \$10,000, from Andrew Carnegie, for a public library.

Harvard Medical School, \$1,000,000, from John D. Rockefeller; \$250,000, from Mrs. C. P. Huntington; \$100,000, from James Stillman; \$471,225, from others.

Harvard University, \$450,000, by the will of George Smith; \$100,000, by the will of Robert C. Billings; \$100,000, by the will of Jacob Wheelock.

Haverford College, \$50,000, from Mrs. Charles Roberts.

Iowa City, Iowa, \$25,000, from Andrew Carnegie, for a public library.

Las Vegas, N.M., \$10,000, from Andrew Carnegie, for a public library.

Lehigh University, \$5000, from Warren A. Wilbur.

Little Falls, Minn., \$10,000, from Andrew Carnegie, for a public library.

Littleton, N.H., \$15,000, from Andrew Carnegie, for a public library.

London, Ohio, \$10,000, from Andrew Carnegie, for a public library.

Maquoketa, Iowa, \$10,000, from Andrew Carnegie, for a public library.

Massachusetts Institute of Technology, \$100,000, by the will of Robert C. Billings.

Melrose (Mass.) Public Library, \$25,000, from Andrew Carnegie.

Mt. Clemens, Mich., \$15,000, from Andrew Carnegie, for a public library.

Nakoma, Ind., \$20,000, from Andrew Carnegie, for a public library.

New Albany (Ind.) Public Library, \$35,000, from Andrew Carnegie.

New Brunswick (N. J.) Public Library, \$50,000, from Andrew Carnegie.

Newton, Kan., \$10,000, from Andrew Carnegie, for a public library.

New York Botanical Garden, \$5000, from Mrs. George Whitfield Collett.

Oskaloosa, Iowa, \$20,000, from Andrew Carnegie, for a public library.

Paris, Ill., \$18,000, from Andrew Carnegie, for a public library.

Redfield, S.D., \$10,000, from Andrew Carnegie, for a public library.

Reno, Nev., \$15,000, from Andrew Carnegie, for a public library.

Rochester Academy of Medicine, \$5000, from Charles T. Ham, for medical research.

Teacher's College, Columbia University, \$250,000, from an anonymous donor.

Tipton, Ind., \$10,000, from Andrew Carnegie, for a public library.

University of Chicago, \$1,250,000, from John D. Rockefeller.

University of Pennsylvania, \$2500, from William Ivins; \$2500, from James Hay; \$5000, from Ralph C. Stewart; land valued at \$12,000, from Gen. Isaac C. Wistar; anonymous gifts of \$15,000.

University of Wooster (Ohio), a conditional gift of \$100,000, from Dr. D. K. Pearson; \$5000, from the directors of the Pennsylvania Railroad; \$100,000, from Andrew Carnegie; \$50,000, from L. H. Severance.

Vassar College, a conditional gift of \$200,000, from John D. Rockefeller.

Washington (Mo.) University, \$25,000, by the will of Geo. E. Leighton; \$20,000, by the will of William E. Huse.

Washington and Lee University, \$5000, from John D. Rockefeller; \$30,000, by the will of Mrs. S. P. Lees.

Waukesha (Wis.) Public Library, \$15,000, from Andrew Carnegie.

Waynesburg (Pa.) College, \$36,000, from various donors.

William Jewell College, a conditional gift of \$25,000, from John D. Rockefeller.

San Bernardino, Cal., \$15,000, from Andrew Carnegie, for a public library.

Santa Rosa, Cal., \$20,000, from Andrew Carnegie, for a public library.

Saratoga (N.Y.) Public Library, \$20,000, from Andrew Carnegie.

Stevens Institute of Technology, \$5000, from Alexander C. Humphreys.

Syracuse University, \$100,000, from John D. Rockefeller.

Yale University, \$5000, from the class of 1876; \$100,000, by the will of

Mrs. Lila Currier.

Yankton (S.D.) Public Library, \$10,000, from Andrew Carnegie.

#### APPOINTMENTS.

Dr. A. F. Adams, assistant in histology in the University of Toronto. — Dr. Leon Asher, professor of physiology in the university at Bern. — Prof. Saverio Belli of Turin, professor of botany in the university at Cagliari. — Dr. Max Belowsky, custodian of the Mineralogical Petrological Institute in Berlin. — Dr. Max Bleibtreu, professor of physiology in the University at Bonn. — Dr. Georg Böhn, honorary professor of geology in the university at Freiburg i. B. — Dr. G. Brandes of Halle, scientific director of the zoological gardens there. — Dr. H. C. Bumpus, director of the American Museum of Natural History. — Dr. Wesley R. Coe, assistant professor of comparative anatomy in Yale University. — Dr. John M. Coulter, professor of botany in the Manila Normal School, Philippines. — Dr. Otto Drasch, professor of histology and embryology in the university at Graz. — Théophile Durand, director of the botanical gardens at Brussels. — M. H. Embler, assistant in biology in the University of Toronto. — Dr. A. Ernst, docent for botany in the university at Zurich. — Dr. Ferdinand Filarsky, custodian of the botanical section of the Hungarian National Museum at Budapest. — Dr. Alexander Fleroff, docent for botany in the university at Moscow. — C. M. Fraser, assistant in zoology in the University of Toronto. — Dr. Ph. Glangeaud, adjunct professor of mineralogy in the university at Clermont, France. — Dr. Caswell Grave, director of the U.S. Fish Commission Station at Beaufort, N.C. — Prof. J. W. Gregory, acting head of the geological survey of Victoria. — Dr. Grinchant, adjunct professor of mineralogy in the university at Caen, France. — Dr. A. C. Haddon, advisory curator of the Horniman Museum at Forest Hill near London. — Dr. R. W. Hall, instructor in biology at Lehigh University. — Dr. Fr. C. C. Hansen, professor of anatomy in the university at Copenhagen. — C. Willard Hayes, geologist in charge of geology on the U.S. Geological Survey. — Dr. E. Johann Gerhard Holm, professor and director of the paleontological section of the Royal Natural History Museum in

Stockholm. — Dr. R. E. Hooper, assistant in histology in the University of Toronto. — Dr. Jaroslav J. Jahn, professor of geology and mineralogy in the Brünn Technical School. — Dr. Max Koernicke, docent for botany in the university at Bonn. — Dr. Richard Kolkwitz, botanist in the royal water-testing establishment in Berlin. — Dr. H. B. Kümmel, state geologist of New Jersey. — E. A. Macallum, assistant in biology in the University of Toronto. — Dr. W. J. Macallum, assistant in histology in the University of Toronto. — Dr. S. Magocsy-Dietz, professor of vegetable morphology and physiology in the university at Budapest. — Dr. R. Martin, professor of anatomy in the university at Giessen. — Dr. Franz Wilhelm Negr, docent for botany in the university at Munich. — Dr. Paul Parnuntier, associate professor of botany in the university at Besançon. — Dr. Paulke, docent for geology in the university at Freiburg i. B. — Dr. W. H. Piersol, instructor in biology and histology in the University of Toronto. — Dr. F. Ptienger, docent for geology and paleontology in the university at Tübingen. — Dr. Ernst, Freiherr Stromer von Reichenbach, docent for paleontology and geology in the university at Munich. — Dr. Adalar Richter, professor of botany in the university at Klausenberg. — W. M. Smallwood, associate professor of zoölogy in Syracuse University. — Dr. Srdinko, docent for histology and embryology in the Bohemian University at Prag. — Dr. Studniczka, docent for zoölogy and comparative anatomy in the Brünn Technical School. — R. B. Thompson, assistant in botany in the University of Toronto. — Dr. Wilhelm Trabut, professor extraordinary of mineralogy in the university at Vienna. — Dr. Karl von Tubeuf, head of the biological division of the Imperial Health Department of Germany. — Dr. M. E. Wadsworth, geologist for the Pennsylvania State Board of Agriculture. — Henry L. Ward, custodian of the Public Museum at Milwaukee. — Dr. Eugen Warming, director of the Geological Survey of Denmark. — Dr. S. H. Westman, assistant in histology in the University of Toronto.

#### RETIRED.

Dr. Chr. Aurivillius from the charge of the entomological collections in the Royal Swedish Museum. — Professor W. H. Brewer from the chair of agriculture at Yale after thirty-seven years of service. — Dr. E. Bugnion from the chair of anatomy in the university at Lausanne. — François Crépin from the directorship of the botanical gardens at Brussels. — Miss Susan M. Hallowell from the chair of botany at Wellesley College. — Professor R. Sadebeck from the directorship of the Botanical Museum at Hamburg. — Professor E. B. Tylor from the keepership of the University Museum, Oxford.

## DEATHS.

Mr. Alfred W. Bennett, the well-known English botanist, January 23, aged 69. — Giuseppe Camillo Giordano, professor of natural history in the Technical Institute at Naples, November 17. — Professor Alpheus Hyatt, at Cambridge, January 15, aged 63. — Professor Axel Key, anatomist and bacteriologist, at Stockholm, December 27. — Dr. Johannes Christoph Klinge, head botanist of the St. Petersburg Botanical Gardens, aged 51. — J. H. Krelage, botanist (Liliaceæ), in Belgium, December 1. — Professor Ivan Muschketoff, geologist of the St. Petersburg Mining Institute, January 25. — C. L. A. de Nicéville, state entomologist of India, at Calcutta, December 3, of malarial fever. — Charles Roberts, British surgeon and naturalist, January 8. — Dr. E. Selenka, professor of zoölogy in the university at Erlangen, January 20, aged 60. — Flaminio Bandi de Selvi, entomologist (Coleoptera), at Turin. — James P. Shipman, local geologist at Nottingham, England, November 21, aged 53. — Dr. Charles Stuart, an English naturalist. — T. T. T. Thorell, arachnologist, at Helsingborg, Sweden, December 23, aged 71. — P. C. Truman, entomologist, at Volga, So. Dakota, October 27.

(No. 424 was mailed April 24.)





